

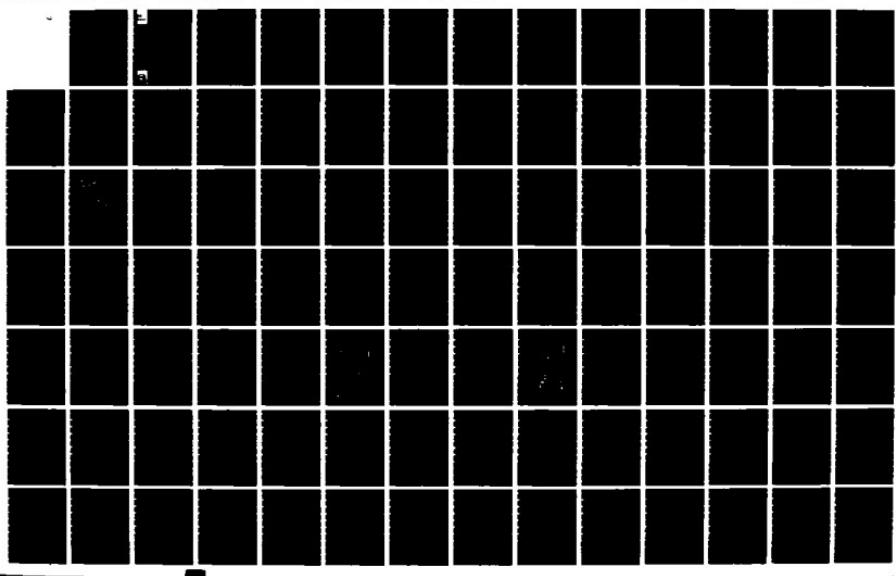
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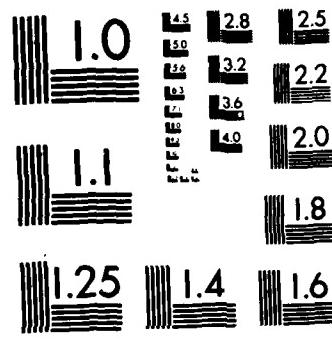
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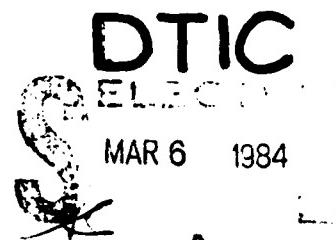
TECHNICAL REPORT

EVALUATION OF METHODS FOR SAMPLING  
VEGETATION AND DELINEATING  
WETLANDS TRANSITION ZONES IN  
SOUTHERN LOUISIANA,  
JANUARY 1979-MAY 1981

c.

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October 1983

Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
-Nine study sites in the Mississippi Delta region of Southern Louisiana, representing both freshwater and brackish marshes and freshwater swamps, were studied in order to develop data that can be used in conjunction with soil and hydrologic data to develop techniques for wetland delineation. In Phase I, numerous methods were evaluated for sampling trees, shrub, and herbaceous layers in three sites dominated by each of the different strata.		

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20. ABSTRACT (Continued).

Phase II consisted of field verification of the selected methods in terms of adequate sample size, efficiency, accuracy, and ability to delineate transition zones at six additional wetland sites.

Testing of the recommended methods resulted in a recommended sampling strategy based on a series of transects at each site composed of contiguous quadrats to determine density. The line-intercept modification was recommended for determining cover.

Although most stands in the region were found to be similar in type and composition, variability among sites and patterns of zonation was great enough that criteria based on structure could not be established to delineate zones of transition.

Several vegetative criteria, including total abundance patterns, species density, species composition trends, indicator species groups, and continuum indices were evaluated as delineation criteria. On the basis of the results at the Phase II study sites, continuum index ranges were proposed to delineate wetland, transition, and upland zones in Louisiana. These ranges were found to allow consistent interpretations among results from three vegetation strata..



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## SUMMARY

This study is one of five regional studies of wetland transition zones contracted by the United States Army Corps of Engineers Waterways Experiment Station.

The primary objective of this study was to evaluate various quantitative vegetative sampling methods to determine the most sensitive, reliable, accurate, and efficient method for use in delineating wetland vegetation boundaries in the south-central United States. Data obtained will be used in conjunction with soil and hydrologic data to develop techniques for wetland delineation.

The study was conducted in southeastern Louisiana on a site extending from just west of Vermillion Bay to the Pearl River along the Mississippi state line and from the Gulf of Mexico north to a line running approximately along 31°N latitude. The area lies entirely within two zones of the Gulf Coastal Province.

Nine study sites in the Mississippi Delta Region of southern Louisiana representing both freshwater and brackish marshes and freshwater swamps were studied in order to develop a sensitive, reliable, and accurate method for determining the boundaries of the transition zone between wetland and upland areas. Phase I involved the evaluation of numerous methods for sampling tree, shrub, and herbaceous layers in three sites dominated by each of the different strata. Phase II consisted of field verification of the selected methods in terms of adequate sample size, efficiency, accuracy, and ability to delineate transition zones at an additional six wetland sites.

### Phase I

In Phase I, three study sites were used to evaluate selected methods for delineating the three different physiognomic characteristics found in the study area: brackish marsh, bald cypress, and shrub-dominated intermediate marsh.

Because cover (vertical projection of the crown or basal area of an individual) and density (the number of individuals per unit area) are the two most important quantitative parameters, according to Mueller-Dubois and Ellenberg (1974), six types of cover measurements and two density techniques were evaluated. Cover measurement techniques included: crown-diameter (trees and shrubs); quadrat charting (low herbaceous plants); loop-frequency (low herbaceous); point-intercept (herbs, shrubs, trees); line-intercept (herbs, shrubs, trees); and visual cover estimation (herb, shrubs, trees). Quadrat- and distance-based techniques were evaluated for density.

Data were determined for techniques to measure trees, shrubs, and herbaceous plants. In summary, the 100-m<sup>2</sup> circular quadrats were the most efficient and accurate method for density and basal area determinations for trees. The line-intercept cover modification was used to supplement the density-based methods to provide a balanced species composition evaluation.

For shrub density and cover, two combination methods were effective, including the 4-m x 4-m density quadrats with visual estimates of cover in each quadrat. The other method was the 1-m-wide perpendicular belt transect for density, using one edge of the belt for line-intercept cover measurements. When species composition determination was the objective of the study, the belt transects were recommended; when total density was most important, the quadrats were recommended.

Where identification of herbaceous plant species presence/composition or total density/cover was important, the combination of 0.125-m<sup>2</sup> unit belt transects and the line-intercept modification was the most efficient method. In areas where herbaceous vegetation was very sparse, belt transects with 0.250-m<sup>2</sup> units and a visual estimate of cover within units was more efficient.

Intensive sampling and comparison of many methods at three Phase I sites indicated it was possible to obtain accurate quantitative data on vegetation amount and species. The major limitation was that many sites do not have either sufficient areal extent or sufficient width of the transitional area to allow the necessary intensity of sampling.

#### Phase II

Following Phase I, a set of sampling methods was selected as the best for sampling trees (overstory), shrubs, and herbs on the basis of accuracy and efficiency in reducing variability. For each stratum, a method based on cover parameter and one based on the density parameters were selected. During Phase II, the field verification process, the selected methods were used and evaluated at six additional study sites. It was then determined whether levels of effort (number of samples) predicted to be adequate in Phase I would indeed be adequate for additional sites and community types representative of Louisiana wetlands. Secondly, the potential utility of these methods for boundary delineation with transect-based studies was determined. The following methods were subjected to Phase II field verification:

- a. Overstory--100-m<sup>2</sup> circular quadrat for density determination combined with Bitterlich variable radius method for dominance (basal area) determination; cover determined either by line-intercept or by cover estimation within the quadrats.
- b. Shrub--One-meter-wide (1-m<sup>2</sup> units) perpendicular belt transect for density determination, combined with line-intercept method for cover determination.

- c. Herb--One-quarter meter-wide ( $0.125\text{-m}^2$  units) perpendicular belt transect for density determination, combined with line-intercept method for cover determination.

The selected Phase II methods were used in transect fashion; that is, the sampling units were arranged linearly along transect lines extending from the baseline (wetland zone) of the sampling site to the upper end (upland zone) of the site. The line-intercept and herbaceous and shrub strata belt transect methods consisted of contiguous units along this line at all sites.

Two sites each were selected for tree (overstory), shrub, and herbaceous plant-dominated wetlands, representing coastal fresh marsh, bottomland hardwood swamp, shrub-dominated fresh marsh, shallow fresh marsh, mixed wetland cypress, and shrub swamp.

Phase II results verified conclusions reached in Phase I regarding sampling efficiency. Although prediction of levels required for sampling remains difficult, predicted values from Phase I remained sufficient.

#### Conclusions and Recommendations

Data obtained for more than 200 species and eight separate community types supplemented and supported previous descriptions of community structure and composition along wetlands transitional gradients. Variability among sites and patterns of zonation were great enough, however, to prohibit the establishment of criteria to delineate zones on the basis of structure.

Transitional zones in the region may be as narrow as 3 m, but usually cover areas about 10 m to 20 m in width and may be much larger. The longest uninterrupted zones occur along boundaries of the coastal marsh community.

Several sampling methods, based on literature review, for overstory, shrub, and herbaceous density and cover were evaluated. The recommended sampling strategy was based on a series of

transects at each site. Each transect was comprised of contiguous 100-m<sup>2</sup> circular quadrats for overstory density, 1-m<sup>2</sup> quadrats for shrub density, and 0.125-m<sup>2</sup> quadrats for herb density. The line-intercept modification was used for cover determination for all strata.

Several delineation criteria, including abundance patterns, species diversity, species compositional trends, indicator species groups, and continuum indices were evaluated. Of these, only continuum indices provided an effective criterion, and has been proposed as potentially useful for delineating wetland, transition, and upland zones in Louisiana.

The following recommendations resulted from the study:

1. The continuum index concept should be tested more fully as a tool for delineation in the southern Louisiana area.
2. Additional data regarding elevation, hydroperiod, soil type, soil moisture, and salinity for the sites should be collected and correlated to vegetational response through ordination or factor analysis techniques.
3. If site-specific methods are used in lieu of the regional criteria approach, appropriate statistical tests should be applied to test for significant differences among zones.
4. The use of various transformations should be evaluated for reducing variability and the amount of sampling replication needed.

## PREFACE

This report was prepared by Environmental Science and Engineering, Inc. (ESE), for the Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES), on studies performed during the period from January 1979 through May 1981. The research was conducted under the auspices of the Wetlands Research Program (WRP). Technical Monitors of the WRP for the Office, Chief of Engineers, were Dr. John R. Hall and Mr. Phillip C. Pierce.

The research was directed by Dr. Stephen W. Fletcher who also wrote the report. Field sampling teams included Mr. Jeff Gore and Mr. John Maxwell of ESE, and Mr. Jerry Usher, Mr. Garrie Landry, Mr. Philip Barbour, and Mr. James LaFrankie, Jr., from the Department of Botany, Louisiana State University. Mr. Landry and Dr. David Hall of the University of Florida Herbarium provided taxonomic support. Ms. Charlotte Sykes, Ms. Kathleen Crase, and Ms. Kathleen Kinsley assisted in production of the report, and Ms. Devorah Levy assisted in analysis and preparation of specimens.

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Dr. Robert Terry Huffman, formerly of EL, served as the Contracting Officer's Representative, and Dr. James Wilson, formerly of EL, served as liaison for WES. Technical supervision was provided by Dr. Hanley K. Smith, Wetland and Terrestrial Habitat Group, EL, and general supervision was provided by Dr. C. J. Kirby, Jr., Chief, Environmental Resources Division, EL, and Dr. John Harrison, Chief, EL. Manager of the WRP was Dr. Smith.

The Commander and Director of WES during this study and the preparation of this report was COL Tilford C. Creel, CE. Technical Director was Mr. Fred R. Brown.

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#### LIST OF ACRONYMS

ANOVA	Analysis of Variance
CAL	Constant Adequacy Level
CAN	Climax Adaptation Number
CI	Continuum Index
$E_c$	Cumulative Relative Efficiency
$H'$	Shannon-Weaver Diversity Index
IS	Similarity Index
IS <sub>(BC)</sub>	Sorenson's Index of Similarity (adapted by Bray and Curtis)
IS <sub>s</sub>	Sorenson's Index of Similarity
IV	Importance Value
RC	Relative Cover
RD	Relative Density
RDo	Relative Dominance
SAN	Species Adaptation Number
SEM	Standard Error of the Mean
VIV	Vegetational Indicator Value
X	Mean

EVALUATION OF METHODS FOR SAMPLING VEGETATION AND DELINEATING  
WETLANDS TRANSITION ZONES IN SOUTHERN LOUISIANA  
(JANUARY 1979-MAY 1981)

PART I: INTRODUCTION

Background

1. Section 404 of the Federal Water Pollution Control Act Amendments of 1972 charges the U.S. Army Corps of Engineers with the responsibility of regulating the disposal of dredged or fill material into waters of the United States. The definition of "waters of the United States" later was expanded by new regulations on July 19, 1977 (Federal Register, 2, 138) which extended the jurisdictional authority to include many additional freshwater and saltwater wetlands.

2. A wetland, as defined in this report, is an area inundated or saturated by ground or surface water at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions (Federal Register, 2, 138).

3. Wetlands tend to grade into upland areas through vegetative transition zones where no sharp line of delineation can be observed. Consequently, it is often difficult to define the upper limits or edges of wetlands and to determine the areal extent of such lands which come under jurisdictional authority.

4. Problems also may occur simply in determining whether an area is a wetland. Environmental Laboratory (1978) has published a description of wetland types within the Gulf coastal region of the United States. This report indicates that not all

wetlands are easily differentiated by type. In such cases, quantitative vegetation surveys would be necessary to determine if a site should be classified as a wetland under jurisdictional authority.

5. Such quantitative determinations, however, must be based upon documentable data and valid sampling procedures. The validity of conclusions regarding the nature and sensitivity of change in vegetation is dependent upon the sensitivity of the sampling method and the reliability of repeated measurements (Stephenson and Buell, 1965). Therefore, the selection of sensitive and reliable sampling procedures is an important initial step for studies designed to delineate edge effects in transitional zones. For the purpose of defining whether a site is actually a wetland, these conclusions must also depend upon the selected method's accuracy in correctly identifying species composition.

6. Since time and cost requirements usually preclude identifying and sampling all individuals within a site, a customary procedure is to sample only a portion of the community within a site. It is necessary to determine the sample size and the number of sample units needed to provide statistically reliable information with minimal effort for each particular site.

#### Objective and Structure of This Study

7. The primary objective of this study has been to evaluate various quantitative vegetative sampling methods to determine methods which are most sensitive, reliable, accurate, and efficient for use in wetland and transition zone determinations in the plant communities found in southern Louisiana.

8. This study consisted of two field sampling phases. Phase I involved the evaluation of several methods for sampling in

tree, shrub, and herbaceous strata (layers). Methods were tested in three sites; in each, the wetland was dominated by different strata. These sites were centered on transitional gradients from wetland to upland. Methods were first evaluated for field efficiency on the basis of the sampling time required to obtain values for the standard error of the mean (SEM), expressed as a specified percentage of the mean.

9. The SEM is a measure of data variance. In this case, it is a measure of the degree of consistency or reliability which can be expected if the same site were sampled several times, and the mean values from each sampling episode were compared. A method with a low variance or SEM would yield the most consistent results, would require the least sampling replication, and thus would be the most reliable. Efficiency is defined in this report as the degree of sampling effort (time) required to obtain a stipulated level of variance and reliability among sample means. The percent standard error of the mean (% SEM) was selected as the parameter for comparing variance in methods utilizing different sample sizes.

10. During Phase I, each method was compared in terms of its accuracy in identifying the true species composition within each site zone. The best methods based on efficiency and accuracy were then evaluated further in Phase II.

11. Phase II consisted of a field verification of these best methods on six additional sites. The methods were evaluated to determine if the Phase I conclusions relating to adequate sample size, efficiency, and accuracy were generally applicable to various sites within the region. Phase II studies were organized to evaluate each method's applicability to transect studies and to delineate vegetative gradients and transition zones.

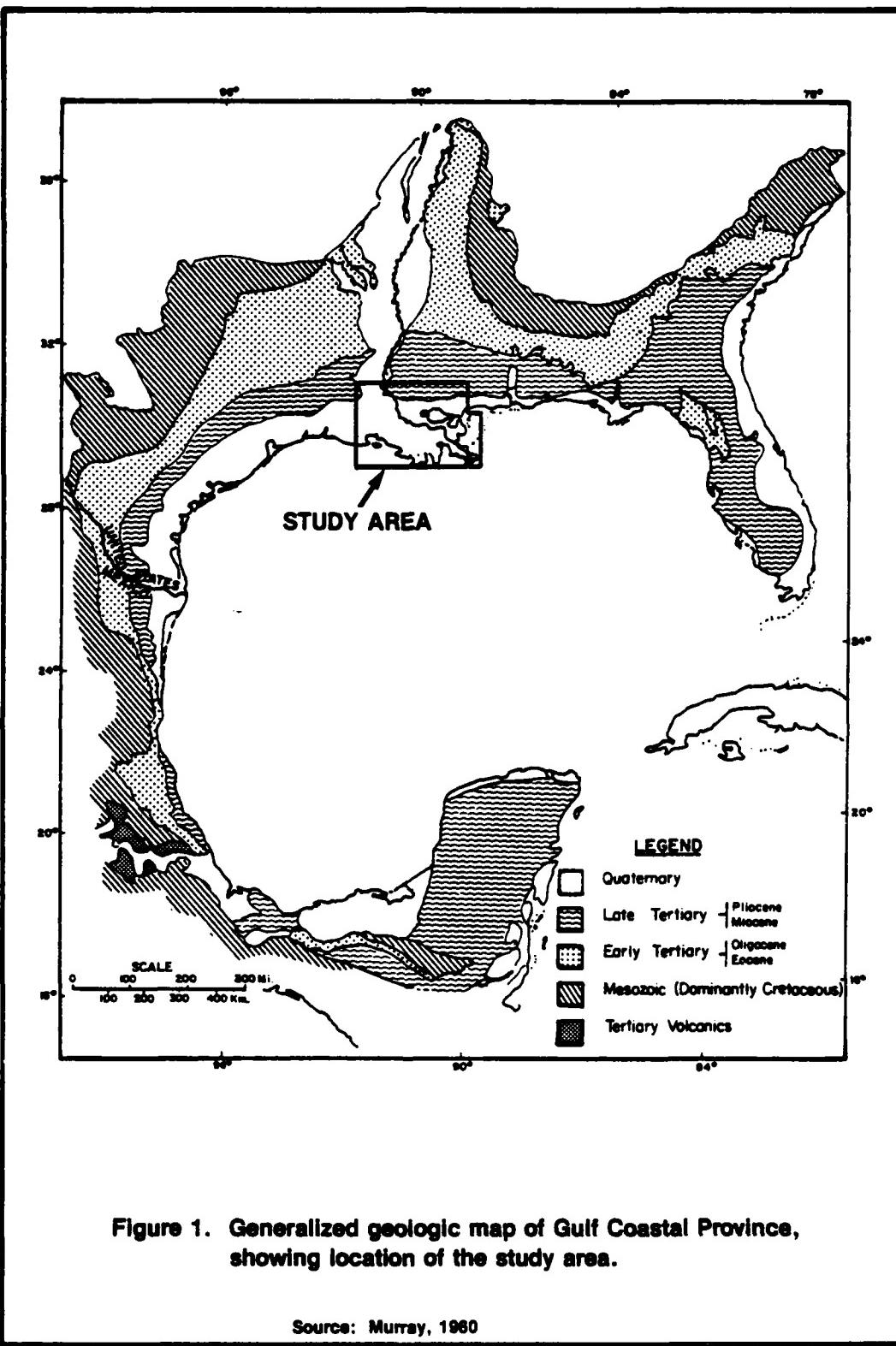
## Regional Environment

### Physiography

12. The area selected for this study consisted of a portion of southeastern Louisiana extending from just west of Vermillion Bay ( $92^{\circ} 30' W$  longitude) to the Pearl River along the Mississippi state line ( $89^{\circ} 30' W$  longitude), and from the Gulf of Mexico north to a line running approximately along  $31^{\circ} N$  latitude. The study area lies entirely within two zones of the Gulf Coastal Province (Figures 1 and 2).

13. The southern portion of this province is comprised of relatively recent Quaternary deposits of marine origin overlain by recent deposits from the Mississippi River system. The coastal zone of this area, known as the Deltaic Plain, is an area of active submergence caused by geologic subsidence (Russell and Howe, 1935). At the same time, it is an area of heavy alluvial deposition and delta formation, due to the effects of the Mississippi River. The pattern of delta formation and shifting has been described by Van Lopik (1955) and Morgan and Larimore (1957). Studies have shown that the delta of the Mississippi River in recent times has migrated within an area of eastern Louisiana from Vermillion Bay on the west to Chandeleur Sound on the east (Russell and Howe, 1935). Within this region, there is a complex of low-lying wetlands subject to the continually altering patterns of fresh- and saltwater influence. Consequently, much of the gradation in vegetation is that between fresh- and saltwater wetlands, rather than between wetlands and uplands. Uplands in many parts of this region may be restricted to natural levees. The Deltaic Plain extends inland 20 to 40 miles from the coast and includes Lake Pontchartrain and Lake Maurepas.

14. Elevations within the Deltaic Plain zone generally are less than 5.0 meters (m) (16.5 feet) above mean sea level (msl),



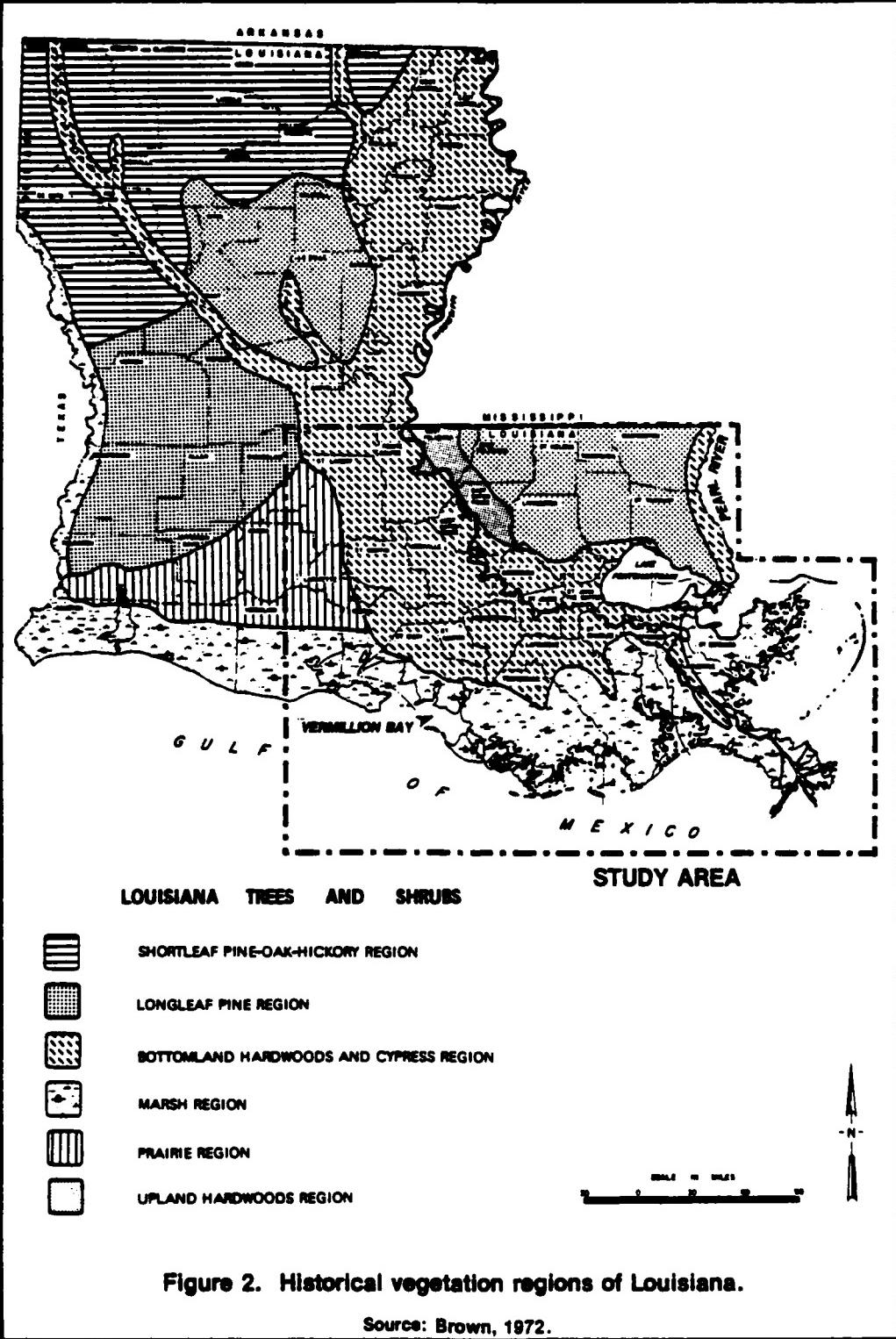
with level topography. Soils consist of peats, mucks, and alluvial clays overlying the silts and clays of marine origin.

15. Similar low-lying, recently deposited areas extend north through the study area along the floodplains of the Mississippi, Atchafalaya, and Pearl Rivers. Within these broad floodplain zones, physiographic features consist of lakes, backwaters, old river channels, and natural levees.

16. The remaining portion of the study area lies within the Late Tertiary zone of the Gulf Coastal Province, an area where subsidence and deltaic processes have not been major factors in soils formation. Elevations range from 5.0 m (16.5 feet) to 100 m (330 feet). To the east of the Mississippi River system, the topography is characterized by relatively flat, sandy plains dominated by flatwoods and loessial soils on higher grounds, broken by numerous small streams and bayous which flow slowly to the Pearl River or Lake Pontchartrain. Along the east side of the Mississippi River north of Baton Rouge and in the foothills along some tributaries of the Atchafalaya system (these areas comprise the upland region of the study area west of the Mississippi River), the topography becomes more varied, with numerous ravines and upland slopes.

#### Vegetation

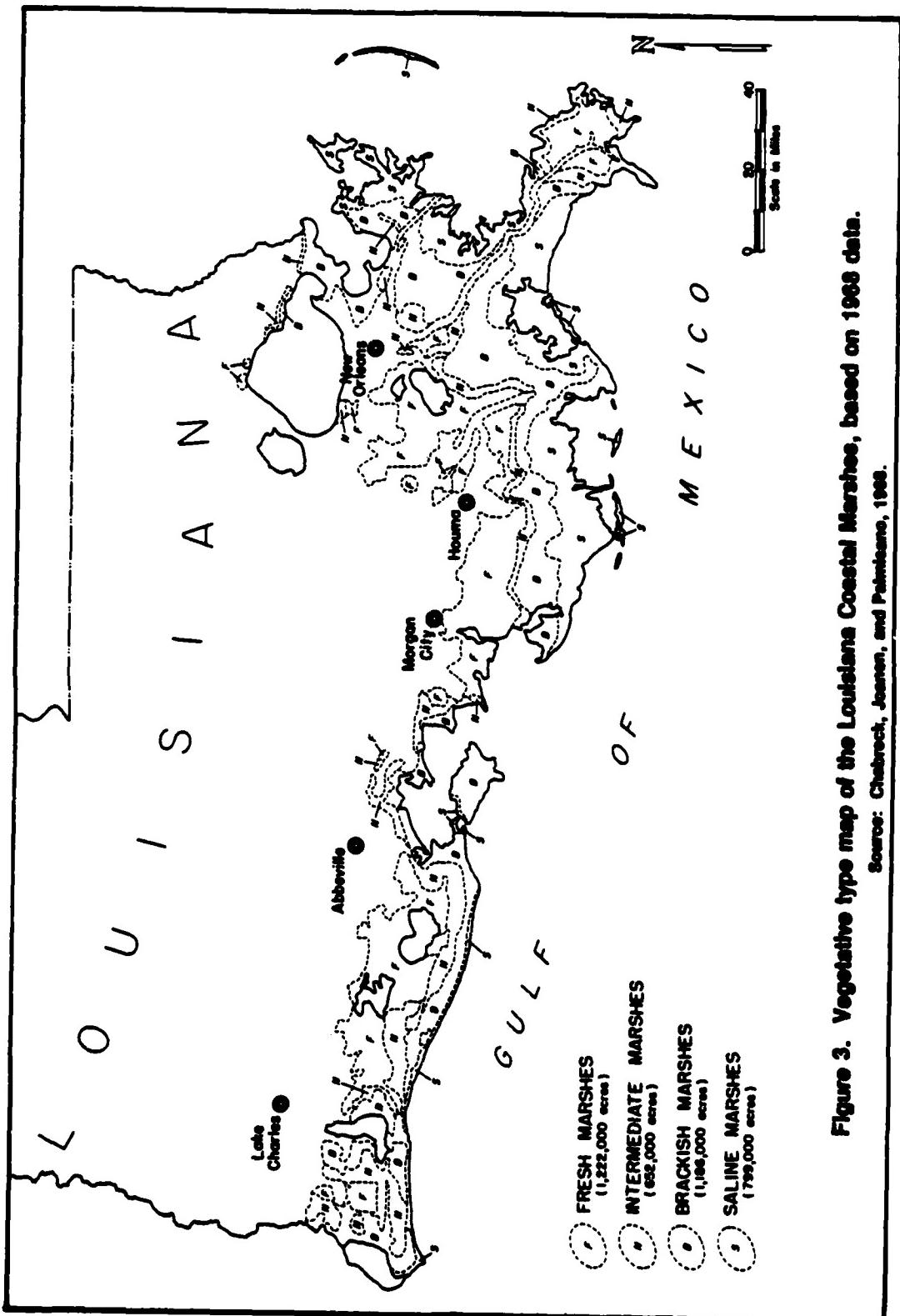
17. The distribution of major vegetation types within the study area closely follows physiographic patterns. Five major regions with distinctive dominant vegetation types can be delineated in the study area: marsh, bottomland hardwoods and cypress swamp, prairie, longleaf pine, and upland hardwoods regions. Figure 2 illustrates these major vegetative regions of Louisiana. Within these regions, several major marsh, swamp, and upland community types occur. These major types are characterized in the following sections in terms of typical species and hydrologic conditions, except for the prairie region, in which



virtually all of the native vegetation has been converted to agriculture.

18. Marsh communities. The marsh region shown in Figure 2 corresponds to the Louisiana Coastal Marshes defined by the Louisiana Wildlife and Fisheries Commission (1949). The portion of these marshes within the study area encompasses virtually all of the Deltaic Plain. These marshes have been mapped by Chabreck (1972) as fresh, intermediate, brackish, and saline marsh. Figure 3 shows a definite zonation pattern of these marsh types. Saline and brackish marsh types almost always grade into intermediate or fresh marshes rather than into upland communities, and thus, the species characteristic of saline and brackish marsh communities rarely occur adjacent to upland and transitional zones. Therefore, the dominant plants of the saline marsh (Spartina alterniflora, Distichlis spicata, and Batis maritima) usually are not prevalent adjacent to wetland-upland transition zones. Plants common to the fresh and intermediate marshes usually are more characteristic of the wetland edges or transition zones between coastal marshes and uplands.

19. Louisiana coastal marshes were first separated into four categories--saline, brackish, nearly fresh, and fresh--by Penfound and Hathaway (1938). Almost all researchers since then have used essentially these same categories and definitions (O'Neil, 1949; Chabreck, Joosten, and Palmisano, 1968; Chabreck, 1970, 1972; Palmisano, 1970; Palmisano and Chabreck, 1972; Chabreck and Palmisano, 1973; Montz, 1977a; U.S. Army Engineers District, New Orleans, 1977). Penfound and Hathaway (1938) described the saline marsh as a Spartina alterniflora consociation in which smooth cordgrass (Spartina alterniflora) forms nearly monospecific stands over extensive areas. Penfound and Hathaway (1938) characterized saline marshes as occurring in waters of 2 to 5 percent salinity and a flooding depth of less than 4 inches. Chabreck (1972) found soil-water salinity to be somewhat lower.



**Figure 3. Vegetative type map of the Louisiana Coastal Marshes, based on 1988 data.**

Source: Chabreck, Joannen, and Petrone, 1988.

20. Although smooth cordgrass is the dominant species of the saline marsh, other species commonly present are black rush (Juncus roemerianus), saltgrass (Distichlis spicata), saltmeadow cordgrass (Spartina patens), and saltwort (Batis maritima) (Chabreck, 1972; Montz, 1977a). In general, species diversity is lower in the saline marsh than in other marsh categories; both Chabreck (1972) and Montz (1977a) found a total of only nine species present. As marshes grade away from zones of generally greater tidal inundation and salinity, there is a general grade from stands of pure smooth cordgrass into black rush and saltmeadow cordgrass, which are also characteristic species of brackish marsh.

21. The brackish marsh, described as a Spartina-Distichlis-Juncus association by Penfound and Hathaway (1938) and Penfound (1952), is dominated by saltmeadow cordgrass, saltgrass, and black rush in pure stands or mixtures of these species. Chabreck *et al.* (1968) have shown that this category reaches its greatest extent in the inactive delta zones of southeast Louisiana. Salinities for this category may range from 0.5 to 2.0 percent (Penfound and Hathaway, 1938; Chabreck, 1972). Both freshwater and saline marsh species may occur in this zone, but species with at least some degree of saline tolerance are the most prevalent. Both Chabreck (1972) and Montz (1977a) found the number of species to be between that of the saline marsh and that of the intermediate and fresh marshes. The more salt-tolerant species, such as smooth cordgrass, black rush, saltgrass, and saltwort, effectively reach their landward limits in this zone (Chabreck, 1972; Montz, 1977a; Environmental Laboratory, 1978). Species reaching their seaward limits are big cordgrass (Spartina cynosuroides), three-cornered grass (Scirpus olneyi), and roseau (Phragmites australis). The brackish marsh grades into saline marsh on the seaward side, into intermediate marsh on the landward side, into widgeon grass (Ruppia maritima) dominated seagrass beds in deeper water, and through saltgrass and shrubby transitional zones into uplands.

22. Originally termed "nearly fresh" marsh by Penfound and Hathaway (1938), these marshes have been termed intermediate marshes by Chabreck et al. (1968) and other more recent investigators (Chabreck, 1970, 1972; Palmisano, 1970; Palmisano and Chabreck, 1972; Chabreck and Palmisano, 1973; Montz, 1977a; Environmental Laboratory, 1978; U.S. Army Engineers District, New Orleans, 1977). Intermediate marshes represent a transitional zone between fresh and brackish marshes. Gradients into upland areas usually are characterized by a zonal cane community dominated by roseau or big cordgrass (Penfound and Hathaway, 1938). Although there is an overlap of brackish and freshwater species, the latter often are more prevalent. Montz (1977a) found saltmeadow cordgrass to be dominant in the Vermillion Bay region, but Penfound (1952) states that sawgrass (Cladium jamaicense) forms almost pure stands. Other associated species include alligatorweed (Alternanthera philoxeroides), roseau, bulbtongue (Sagittaria falcata), and three-cornered grass.

23. Chabreck et al. (1968) found that fresh marshes constituted the largest component of the Louisiana coastal marshes, encompassing 1,222,000 acres. Fresh marshes represent the most landward zone of the coastal marshes and may be up to 20 miles wide. Penfound and Hathaway (1938) described these as "strictly fresh" (less than 0.1 percent salinity) marshes dominated by broadleaf cattail (Typha angustifolia) in disturbed areas and by giant bulrush (Scirpus californicus) in undisturbed areas. In a later paper, Penfound (1952) divided fresh marsh into a deep marsh type covered by water throughout most of the growing season and a shallow marsh type covered by water for only a small part of the growing season. Deep marshes were divided into a giant cutgrass (Zizaniopsis miliacea) consociation in the deepest waters, a cattail-bulrush-maidencane (Typha-Scirpus-Panicum) community, and a sawgrass community in the shallow intermediate marshes. Shallow marshes were described as panic grass-horned rush (Panicum-Rhynchospora) communities.

24. Fresh marshes are characterized by a high diversity of species. Both Chabreck (1972) and Montz (1977a) found that fresh marshes had the highest species number (27 and 57, respectively) of the four marsh categories studied. Environmental Laboratory (1978) makes a distinction between the outer coastal plain marshes and the inland marshes, with a much larger number of potential dominants in the inland marshes. In the coastal marshes, Chabreck (1972) found the dominants to be maidencane (Panicum hemitomon), bulltongue, spikerush (Eleocharis sp.), alligatorweed, and saltmeadow cordgrass. Montz (1977a) found bulltongue, alligatorweed, maidencane, saltmeadow cordgrass, and cattail to be the dominant species.

25. Deep marshes of the coastal plain may grade into the intermediate or brackish marshes. Zonation to upland areas is usually through the cypress-tupelo-gum swamp into pine or oak forest (Penfound and Hathaway, 1938). Giant cutgrass occurs along the margins of the cypress-gum swamps and may be a good site indicator of these swamps according to Penfound and Hathaway (1938). The transitional cane (Phragmites australis) zone may also be found along fresh marsh borders.

26. Shallow fresh marshes have been referred to as wet prairies or wet meadows (Environmental Laboratory, 1978), grass-sedge bogs (Garren, 1943), and pitcher-plant lands (Pessin, 1933). Dominant species include panic grasses (Panicum spp.), sedges (Carex spp.), spikerushes, smartweeds (Polygonum spp.), and arrowheads (Sagittaria spp.). Wet prairies typically have mineral soils and are usually associated with open pinelands or with burning or clearing of shrub swamps or bay swamps (Pessin, 1933; Penfound and Watkins, 1937; Wells, 1942; Garren, 1943; Penfound, 1952).

27. Bottomland hardwoods and cypress swamp communities.  
The floodplains associated with the Mississippi, Atchafalaya, and

Pearl Rivers have a hardwood swamp forest vegetation, with cypress-tupelo-gum swamps dominating the lower, more poorly drained portions, and with assorted bottomland hardwood species dominating better drained portions.

28. Cypress-tupelo swamp corresponds to the deep swamp category of Penfound (1952). This community is characterized by flooding throughout all or most of the year (Hall and Penfound, 1943). Dominant or subdominant species may include bald cypress (Taxodium distichum), water tupelo (Nyssa aquatica), swamp black gum (Nyssa sylvatica var. biflora), and red maple (Acer rubrum). Common species include ashes (Fraxinus spp.), buttonbush (Cephalanthus occidentalis), water elm (Planera aquatica), and swamp privet (Forestiera acuminata). Penfound and Hathaway (1938) report that cypress-tupelo-gum swamps in Louisiana are bordered by fresh marsh and by oak or pine forest on the upland side.

29. Shrub swamps generally are early successional areas dominated by a single species and represented by only a few species. Several of Penfound's (1952) shallow swamp communities, including black willow-sandbar willow (Salix nigra-S. interior) and buttonbush-dogwood-willow, fit into this group. Shelford (1954) terms sandbar willow associates and black willow-cottonwood associates as variants of this type. Shrub swamps generally are found in low, moist spots and depositional areas such as sandbars, mudflats, and backwaters. Willows and buttonbush occupy the lower areas, while cottonwood is found on the better-drained sites.

30. Bottomland hardwood communities are characterized by inundation for a period from only a few days to a few months during the growing season. Consequently, it is a highly mixed community extending across a transitional gradient from cypress-gum swamps to upland pine or oak forests. Species present in a given community differ depending upon their tolerance to a given microhabitat factor, especially to the degree of flooding. Classification among different authors becomes confusing due to

the varied flora and to differences among interpretations of wetlands.

31. Several authors (Thieret, 1971; U.S. Army Engineers District, New Orleans, 1977) have made distinctions between "first bottoms" and "second bottoms." First bottoms are the lowest-lying and most recently formed areas of alluvial soil, while second bottoms are old floodplains now inundated by stream water for less than 25 percent of the growing season (Huffman and Forsythe, 1981). Thieret (1971) includes bald cypress-tupelo-gum swamps in the first bottoms group. The U. S. Army Engineer District, New Orleans (1977) lumps the cypress-gum swamp into a wetlands category along with some bottomland hardwood species such as swamp cottonwood (Populus heterophylla), overcup oak (Quercus lyrata), green ash (Fraxinus pennsylvanica), and black willow (Salix nigra).

32. For this report, it is proposed that the category "first bottoms hardwoods" be used to designate those early successional phases which might occur on first bottoms, exclusive of the cypress-tupelo-gum swamp. Huffman and Forsythe (1981) consider such areas to be semipermanently inundated or saturated for a major part of the growing season. Duration of inundation typically exceeds 25 percent of the growing season. Wetland indicators of this community would be red maple, water hickory (Carya aquatica), buttonbush, haws (Crataegus spp.), swamp-privet, green ash, water locust (Gleditsia aquatica), water elm, swamp cottonwood, overcup oak, and black willow.

33. The "second bottoms" delineated by Thieret (1972) would include the more mesic variants of the bottomland hardwoods type. Second bottoms thus represent the upper limits of the transitional forest communities before a true upland forest is reached. Characteristic species include hackberry (Celtis laevigata), sweetgum (Liquidambar styraciflua), American holly (Ilex opaca), ironwood (Carpinus caroliniana), and water oak (Quercus nigra). Whether second bottom bottomland hardwoods are wetlands is questionable at this time; therefore, they were

evaluated as potential transitional areas in this study  
(Environmental Laboratory, 1978).

34. Upland longleaf pine and upland hardwoods communities.

Upland vegetation in the study area generally is restricted to the region north of Lake Pontchartrain, where broad expanses of longleaf pine (Pinus palustris), slash pine (P. elliottii), and shortleaf pine (P. echinata) occupy flat, raised uplands of the longleaf pine region but rarely extend to the lower areas bordering wetlands. Along the edges of these terraces, the upland forests grade into wetlands through oak-pine or oak-pine-hickory forest types in which loblolly pine (Pinus taeda), live oak (Quercus virginiana), water oak, laurel oak, willow oak (Q. phellos), sweetgum, and various hickories (Carya spp.) are common. In areas of early secondary succession, spruce pine (P. glabra) may be abundant locally.

35. Upland hardwood forests may occur in the ravines and slopes along the Mississippi River north of Baton Rouge and along some tributary systems (Bayou Cocodrie, Bayou Des Glaises, Bayou Bouef) to the Atchafalaya River (upland hardwood region). These forests, which are floristically similar to the more northerly oak-hickory forests of the Ozark-Ouachita Highlands (Little, 1971, Brown, 1972), contain white oak (Q. alba), cherrybark oak (Q. falcata var. pagodaefolia), southern red oak (Q. falcata), white ash (Fraxinus americana), beech (Fagus grandifolia), southern magnolia (Magnolia grandiflora), dogwoods (Cornus spp.), hickories, and ironwood (Carpinus caroliniana) (Brown, 1972).

Wetland Classification Schemes

36. Wetland types in southern Louisiana have been classified in various ways by numerous researchers. A comparison of several of the more important classification schemes is shown in Table 1.

**Table 1**  
**Comparison of Relevant Wetland Classification Schemes**

Penfound (1952)	Penfound and Hartshaway (1936)	U.S. Army Engineers District, New Orleans (1977)	Environmental Laboratory (1978)	Martin et al. (1953)	Cowardin et al. (1979)
—	—	—	—	—	ESTUARINE Aquatic beds LAOSTRINE, RIVERINE, PAIUSTRINE Aquatic beds
SALTWATER MARSH					
True marsh	Saline marsh; Brackish marsh	Saline marsh; Brackish marsh	Saltwater aquatic wetland; Freshwater aquatic wetland	Inland open fresh water; Coastal open fresh water	ESTUARINE Persistent; emergent wetland
Zonal community	Saltgrass zone	Shrub zone	Saltwater marsh; Saltwater coastal flat	Regularly flooded salt marsh; Coastal salt flat; irregularly flooded salt marsh; Coastal salt meadow	ESTUARINE, RIVERINE Emergent, flat
PRESUMER MARSH					
Deep marsh	Fresh marsh; Nearly fresh marsh	Fresh marsh; Intermediate marsh	Freshwater marsh	Coastal deep fresh marsh	ESTUARINE, RIVERINE Emergent, flat
Shallow marsh	Fresh marsh	Fresh marsh; Intermediate marsh;	Freshwater flat;	Seasonally flooded baseline; Coastal shallow fresh marsh	PAIUSTRINE Flat
Zonal community	Cane zone	Shrub zone	Freshwater marsh	Seasonally flooded baseline; Coastal shallow fresh marsh	PAIUSTRINE Flat
SALTWATER SWAMP					
Black mangrove; Transitional	Zonal mangrove; Shrub zone	Saline marsh; Shrub zone	Salwater swamp	Hangrove swamp	ESTUARINE Intertidal Broad-leaved evergreen
FRESHWATER SWAMP					
Deep swamp	Cypress-gum swamp	Bald cypress-tupelo-gum swamp	Prolonged flooding	Wetland swamp	PAIUSTRINE Forested wetlands; Broad-leaved and needle-leaved deciduous
Shallow swamp	Zonal-willow	Wet bottomland hardwoods; Dry bottomland hardwoods; Shrub swamp	Intermittent flooding	Wetland swamp; Seasonally flooded baseline	Broad-leaved deciduous; Scrub/shrub wetland

Source: FSP, 1981.

37. Table 1 uses Penfound's 1952 classification scheme as a basis against which other schemes are arrayed. The schemes include two national classification systems (Martin et al., 1953; Cowardin et al., 1979), two regional systems (Penfound, 1952; Environmental Laboratory, 1978), and two local systems (Penfound and Hathaway, 1938; U.S. Army Engineers District, New Orleans, 1977).

38. Each of these schemes has some merit. The regional and national schemes are based on logical sequences of classification, yet lack the degree of resolution and description found in the local systems. Table 2 presents a proposed new scheme which is felt to be the most applicable to this project. This scheme has been synthesized from several of the earlier systems. It is most closely related to the U.S. Army Engineers District, New Orleans (1977) description.

39. Huffman and Forsythe (1981) provide an alternative classification of swamp or bottomland forest types, which is excellent for describing and classifying communities. The scheme proposed in Table 2, however, has greater utility for the transition zone study because it is based more on physiognomic or structural features rather than on species composition. It is physiognomic features such as the degree of development of each vegetational strata that most influences sampling methodologies.

40. Botanical nomenclature in this report follows that of Radford et al. (1968), wherever possible. Where local species are not included in Radford et al. (1968), nomenclature follows Godfrey and Wooten (1979), Brown (1972), and Thieret (1972).

#### Quantitative Methodologies Commonly Used to Study Plant Communities

41. Recognition and characterization of plant communities have been primary aims of plant ecologists since the time of early

Table 2  
Proposed Classification Scheme for Wetland  
Communities in Southern Louisiana

<u>Wetland Types</u>	<u>Dominant Life Form</u>	<u>Dominant Species*</u>
I. Aquatic wetlands		
A. Salt water	Submerged herb	Widgeon grass-wild celery
B. Fresh water	Submerged herb	Pondweed-water milfoil
II. Marshes		
A. Saline marsh	Herb	Smooth cordgrass
B. Brackish marsh	Herb	Saltmeadow cordgrass-saltgrass-black rush
C. Intermediate marsh	Herb	Sawgrass-saltmeadow cordgrass-alligatorweed-bulltongue
D. Fresh marsh	Herb	Bulrush-cattail-maidencane-giant cutgrass-bulltongue-smartweed
E. Transitional zones		
1. Salt grass	Herb	Saltgrass
2. Cane	Herb	Roseau-quill cane
3. Shrub	Herb or shrub	Marsh elder-sea oxeye-wax myrtle
III. Swamps		
A. Saltwater swamp	Tree or shrub	Black mangrove
B. Freshwater swamp		
1. Bald cypress-tupelo-gum	Tree	Bald cypress-tupelo-gum
2. Mixed bottomland hardwood		
a. First bottoms	Tree	Cottonwood-overcup oak-red maple-willow-black gum-water hickory
b. Second bottoms	Tree	Hackberry-oak-sweetgum-ironwood
3. Shrub swamp	Shrub or tree	Willow-cottonwood-elderberry-buttonbush

\* See list of common and scientific names, Appendix A.

Source: ESE, 1979.

geobotany and plant geography. Current methods and approaches have evolved over a period of more than a century (Mueller-Dombois and Ellenberg, 1974). Yet, even now, the variety of sampling and analysis methods and the lack of agreement among authorities is staggering.

42. Selection of a methodology is a process which depends upon the resources available for the study, the objectives of the study, and the required accuracy or level of resolution needed for accomplishing the objective. Therefore, before selecting one or more of the various possible methodologies, it is worthwhile to understand its historical perspectives and documented limitations.

43. The two most important quantitative parameters in sampling vegetative communities are cover (the vertical projection of the crown or basal area of an individual) and density (the number of individuals per unit area) (Mueller-Dombois and Ellenberg, 1974). Additional parameters reflecting dominance relations are either variations of these parameters (i.e., basal area), or are synthetic parameters constructed from the above (i.e., frequency, importance value).

44. Various sampling techniques have been proposed for cover measurements, while density techniques generally are either quadrat- or distance-based. Numerous variations or combinations of these methods also have been proposed. Each of these four groups of techniques is discussed in the following paragraphs.

#### Cover Measurements

45. Six basic types of cover measurement were identified as having possible application in wetlands of southern Louisiana. The methods and life forms or physiognomic types for which each is applicable are:

- a. Crown-diameter method--trees and shrubs.
- b. Quadrat charting (cartographic) method--low herbaceous plants.

- c. Loop-frequency method--low herbaceous plants.
- d. Point-intercept (point-contact) method--herbs, shrubs, trees.
- e. Line-intercept method--herbs, shrubs, trees.
- f. Visual cover estimation--herbs, shrubs, trees.

46. Crown-diameter and quadrat charting methods have been documented as having excessive time requirements, which make them inefficient for sampling use in all instances except permanent, long-term monitoring sites (Mueller-Dombois and Ellenberg, 1974).

47. Loop-frequency, point-intercept, and line-intercept methods have all at one time or another been tested against each other or against other methods. Buell and Cantlon (1950) first tested the comparability of data obtained by the line-intercept method to that of quadrat methods in somewhat open, scrubby pine and oak uplands. When cover (from line-intercept technique) and basal area (from quadrats) were converted to relative dominance, the importance of the species with wide-diameter crown forms was increased by using the line-intercept method. Buell and Cantlon felt this method is most useful since arboreal cover is a more direct measure of dominance.

48. Stephenson and Buell (1965) went on to examine the reproducibility of line-intercept results in shrub cover sampling and found that the variances were generally within the desired confidence interval. Thus, the method was reproducible and presumably accurate for use with workers of varied experience.

49. Whitman and Siggeirsson (1954) compared the line-intercept method with all-contacts and basal area contacts variations of the point-intercept method in western range grass. Using the % SEM for the measure of accuracy, they determined that the all-contacts point-intercept would appear to be more efficient on bunch-type graminoid systems than would the basal area contacts variation or the line-intercept method.

50. Johnston (1957) compared the line-intercept, point-intercept, and loop-frequency methods in low grassland. The loop-frequency method estimated cover as being two to eight times greater than that of the other methods, which were approximately equal in results. Hutchings and Holmgren (1959) also found that the loop-frequency method had several inherent positive (overestimation) biases which were considered difficult or impossible to overcome.

51. Considerable use has been made of cover methods in marsh studies, particularly in Louisiana. The simplest method is that of estimating cover within a specified area and expressing it as a cover class. This method generally is considered to be relative or qualitative, but with proper controls it may be considered at least semiquantitative. This method has been used by Montz (1975, 1976a, 1976b, 1977a), Kerwin and Pedigo (1971), and Wikum and Shanholtzer (1978) for rapid surveying of large expanses up to 20 miles wide. Generally, 1-m<sup>2</sup> quadrats have been used for herbaceous vegetation and 10-m<sup>2</sup> quadrats for shrubs and trees. Sampling of 20 to 80 quadrats has been reported as adequate for characterization. This method has the advantages of speed and ease of use; however, it is not strictly valid for statistical analysis of accuracy.

52. The line-intercept method has been used by Chabreck (1972), Chabreck and Hoffpauir (1962), and Chabreck and Palmisano (1973) in sampling Louisiana marshes. The technique for establishing sampling points is similar to that of Montz, except that at each sampling point on a transect, a 5-foot-long, line-intercept unit is used instead of the cover estimation quadrat. This technique, then, makes use of a truly quantitative measure of cover. Both the cover estimation quadrat and line-intercept methods can be used on regular or random, grid or transect bases.

### Density Measurements: Quadrat Methods

53. Freshwater wetland communities with vertical stratification, such as swamps, are usually sampled with either the quadrat method (plot sampling) for tree, shrub, and herb strata, or with a combination of the quadrat method (to sample herb and shrub strata), and the point-centered quarter method (plotless sampling) for the tree stratum.

54. According to Oosting (1956), quadrats are 2-dimensional sampling plots that can be used in connection with studies of ecological problems of succession, zonation, or classification. In practice, they have been used to quantify all strata in various communities. The size of quadrats varies with the type of stratum measured. According to Oosting (1956) and Cain and Castro (1959), the quadrat size used in analyzing vegetation typically is 100 m<sup>2</sup> for the tree layer, 4 m<sup>2</sup> to 16 m<sup>2</sup> for woody undergrowth up to 3 m in height (shrubs), and 0.1 to 1 m<sup>2</sup> for the herb layer. Parameters such as species density, frequency, and dominance (i.e., basal area) may be assessed in all layers. However, percent cover usually is utilized as the measure of dominance in the herb stratum.

55. Size determination and number of plots within a stand are of great importance and should be determined during sampling. The typical quadrat sizes mentioned above may be suitable for most studies, but adequacy can truly be established only by testing. Such testing usually has been done using nested plots and species-area curves or by running means.

56. Greig-Smith (1964) has pointed out that the minimal area concept and consequently the species-area curve are useful only in comparing or describing community characteristics. These concepts are not adequate for direct determination of the most

suitable quadrat size for quantitative sampling. Thus, these concepts are useful only as an approximation of the percent area of a stand which needs to be sampled, and not as a measure of the size of the quadrat. Optimal quadrat size is determined by factors such as minimization of variance of mean, ease and speed of recording, and considerations of edge effect.

57. Several studies (Clapham, 1932; Bormann, 1953) have shown that sample accuracy is affected by shape of the quadrat. This effect may be due to nonrandom patterns in vegetation and to "edge effects" caused by individuals which occur on or overhang an edge. The shape of the quadrat may vary from square to rectangular to circular. However, it has been shown by Greig-Smith (1964) that the rectangular quadrat is usually more accurate than the square shape, and that the smallest quadrat which can be used with negligible edge effects generally is the best size.

58. Appropriate sample size based on the number of plots can be determined by statistical analysis of variances about the sample mean. The ratio of the SEM to the mean can be used as a measure of the accuracy of a sample size. By setting a predetermined limit of accuracy (such as a 15-percent SEM), the minimum valid sample size can be determined. However, such error terms apply to random populations only, and are not truly valid for individuals of a single species since these are infrequently distributed (Greig-Smith, 1964). Sample sizes computed by this method should be regarded only as approximations of the minimum adequate sample size.

59. Since the variance and SEM are specific to individual stands or communities, they are not known prior to sampling an area. Therefore, adequate sample size cannot be wholly predicted prior to sampling. During sampling, estimates of the minimum sample size can be made in one of three ways. The most basic of the three methods directly calculates the SEM with successively larger sample sizes. In this method, the SEM is first calculated after a specified number of samples is collected. If the

resultant SEM does not reach the required goal, additional samples are taken and a new SEM is calculated on the basis of the cumulative sample size. The process is repeated until the goal is reached.

60. Unless sophisticated calculating devices are available, SEM calculation is too time-consuming for regular field use. A less time-consuming estimation can be obtained by calculating and plotting the running mean, which will fluctuate less as sample size increases. A predetermined level of variation can be used as a criterion of adequate sample size. A third method which could be used in field estimation of sample size is the species area curve.

61. For both the running mean and species area curve methods, however, the chosen level of sample adequacy should result in a satisfactory level of SEM. Therefore, when using these methods, their relationships to SEM levels should be known for the community being sampled. Thus, in the initial sampling of a stand or community type, Greig-Smith (1964) suggested that a sufficiently large sample be taken so that the relation between the running mean variation and SEM can be estimated.

62. Numerous investigators have relied on quadrat methods for all strata and have modified plot size, shape, and number for each stratum. In a Louisiana bottomland swamp, Thieret (1972) established forty 10-m by 10-m (0.025-acre) quadrats in a regular pattern along five rows for sampling woody plants. Forty 1-m by 1-m quadrats were used for cover estimates and species composition of the herb stratum. Herb cover in each quadrat was estimated using cover classes. Thieret recognized that a more accurate and objective analysis for herbs would have been desirable.

63. Reiners (1972) studied contiguous upland oak forest, marginal fen, and cedar swamp communities in Wisconsin by establishing rectangular 20-m by 80-m sampling units in each type. The sampling units were contiguous, and each unit was divided into sixteen 10-m by 10-m quadrats.

64. Other strictly quadrat methods have been used by Buell and Cantlon (1950), Knight (1975), Whitaker and Niering (1975), and Peet and Loucks (1977). Total sampling area in these studies ranged from 400 m<sup>2</sup> to 5000 m<sup>2</sup> for trees, 32 m<sup>2</sup> to 1000 m<sup>2</sup> for shrubs, and 10 m<sup>2</sup> to 100 m<sup>2</sup> for herbs. These areas resulted in sampling intensities of 25 to 100 percent of the study area for trees, 2 to 6 percent for shrubs, and 1 to 3 percent for herbs.

65. Numerous authors (Adams, 1963; Cooper and Waits, 1973; Auclair *et al.*, 1976; Vogel, 1972; Kirby and Gosselink, 1976; White *et al.*, 1978; Hopkinson *et al.*, 1978) have used small quadrats for productivity studies in which density was measured on a peripheral basis and usually was not used in data assessment.

#### Density Measurements: Distance Methods

66. Distance or "plotless" methods do not require a prescribed sampling area such as a quadrat. Distance methods are popular since they can be performed with relative speed and ease in the field for determining density, basal area, and frequency for tree species in forested communities.

67. Although plotless sampling methods exist for measuring frequency, cover, and density, this section will treat only those methods relating to density measurement. Measurements for frequency (point-intercept methods) and cover (point-intercept and line-intercept methods) have been discussed previously.

68. Distance methods are based on the premise that the density of trees in an area is a function of the average distance between trees and of the main area of each tree. Instead of directly measuring the number of individuals in a given area, distance methods measure the average distance between trees, and density per area is then computed from this value. The methods

evaluated for possible application in wetlands of southern Louisiana include:

- a. Bitterlich variable radius--trees.
- b. Nearest neighbor--trees and shrubs.
- c. Closest individual--trees and shrubs.
- d. Random pairs--trees and shrubs.
- e. Point-centered quarter--trees and shrubs.
- f. Wandering quarter--trees and shrubs.

69. Two basic groups of distance measurement techniques exist: (1) the Bitterlich variable radius methods which determine stem cover or basal area through a modification of point sampling techniques, and (2) distance methods developed at the University of Wisconsin which measure the distance between trees.

70. The variable radius method introduced by Bitterlich (1948) consists of a sighting stick with a crosspiece at one end. The observer stands at a point and records all trees in a circle which appear to be wider than the crosspiece as viewed along the stick. The number of trees recorded can be converted directly to basal area per unit area. More recent adaptations of this method have used optical instruments for measuring lateral displacement. Basic limitations of this method are that basal area is the only parameter measured and that visibility and usefulness are limited in low light and dense undergrowth. The method is quickly learned, easily used, and highly reproducible (Mueller-Dombois and Ellenberg, 1974).

71. All of the following distance methods are based on an assumption of random distribution of individuals. However, each of the methods measuring tree-to-tree distances appears to be slightly less accurate than the point-to-tree methods because distances from points to trees are more nearly random (Pielou, 1959). In some cases, various distance methods have been tried on herbaceous vegetation (Dix, 1961; Greig-Smith, 1964; Risser and Zedler, 1968) and found to be inaccurate due to the usually nonrandom, strongly aggregated patterns of herbaceous vegetation.

The methods tend to underestimate densities of contagiously distributed species (those in which individuals tend to occur in clumps) and overestimate regularly distributed individuals.

72. The nearest-neighbor method (Cottam et al., 1953; Cottam and Curtis, 1956) selects pairs of individuals closest to randomly selected points. The distance between the two individuals nearest to the randomly selected point is measured.

73. The closest individual method (Cottam et al., 1953; Cottam and Curtis, 1956) measures the distance from a randomly selected point to the nearest tree. In the random pairs method (Cottam and Curtis, 1949; Cottam, 1955), the nearest tree to the point serves as a base for measuring a distance to a second tree. Although one of the most popular of the distance methods, it has been supplanted to a large extent by the point-centered quarter method.

74. The point-centered quarter method (Cottam and Curtis, 1956) is considered to be the most effective of these four types of distance sampling techniques for the following reasons:

- a. It does not require a correction factor.
- b. It is simplistic in design and use.
- c. It is four times as sampling-intensive.

75. In the point-centered quarter method, four distances are measured from each randomly or systematically selected sampling point. Four quarters are established at the point through a cross formed by the two lines. One line is a selected compass direction and the second is a line perpendicular to the compass direction through the point. The distance to the midpoint of the nearest tree from the sampling point is measured in each quarter.

76. The limitations of this method, identified by Mueller-Dombois and Ellenberg (1974), are that:

- a. Individuals must be located within each quarter.
- b. Individuals should not be measured twice.

- c. It cannot be used on herbaceous vegetation.
- d. It should be used only on randomly spaced individuals.

77. The wandering quarter method (Catana, 1963) compensates somewhat for some of the limitations of the point-centered quarter method. A quarter is established at a sampling point and laid out at a predetermined compass direction which divides the quarter into two, 45° wedge-shaped sections. The nearest tree to the point is measured and becomes the vector of a second quarter. By combining both tree-to-tree and point-to-tree methods, this method is intended to, but does not, compensate completely for variances from random populations (Mueller-Dombois and Ellenberg, 1974).

78. A modification of the wandering quarter method consists of measuring the distance from the sampling point to the nearest individual. From this individual, the distance is measured to its nearest neighbor, and then a third distance is measured to the next nearest neighbor. Therefore, three distances are measured from a single sampling point (Batcheler, 1971). This modification of the wandering quarter method needs much more intensive testing before it is applied for general use, according to Mueller-Dombois and Ellenberg (1974).

79. Following the introduction of the variable ratio (Bitterlich) and distance methods, several studies compared their accuracy and frequency, particularly as opposed to conventional quadrat methods. Shanks (1954) compared the variable radius (prism) method, random pairs method, and 0.25-acre and 0.1-acre circular quadrats, and found wide variability among means of different methods. The random pairs data appeared to come from such a small sample size that an SEM could not be computed without logarithmic transformation. However, Shank's data suggested that just seven variable radius points would be sufficient for a 10-percent SEM. Shanks also estimated that a 5-percent SEM could be obtained by the variable radius method with 42 points and

6 manhours of field time, whereas 60 plots and 24 manhours would be required for quadrat analysis.

80. Rice and Penfound (1955) attempted to compare the variable radius and random pairs methods in oak forest. A comparison of the variable radius and random pairs methods with a total census of about 9 acres led them to conclude that the variable radius method was suitable for basal area, capable of reaching an SEM of about 10 percent for dominant species and 5 percent for total basal area. The 40-point sample was thought to be accurate. They concluded that the random pairs method was not accurate and attributed the error to insufficient sample size. Cottam and Curtis (1955) subsequently showed that an incorrect equation and correction factor had been used. When corrected, the results for density were found to have a 2-percent error. Basal area per species was still inaccurate, probably due to insufficient sample size (less than 30 individuals) for individual species.

81. Rice and Penfound found efficiency of the two methods to be comparable, with field times of 2.5 hours per 40 points for random pairs and 2 hours per 40 points for the variable radius method.

82. Cottam and Curtis (1956) compared four distance methods to quadrat results in three forest stands and an artificial random population in Wisconsin. The four methods were closest individual, nearest neighbor, random pairs, and point quarter. They found that with adequate sample size, all four methods can yield accurate results. Using an SEM level of 4.5 percent for mean distance (which corresponds to 10 percent for calculated density), the closest individual would require 114 to 146 (depending on stand characteristics) points; the nearest neighbor, 59 to 102 points; the random pairs, 50 to 71 points; and the point-quarter method, 26 to 38 points. Although more time per point is required for the point-quarter method, the overall efficiency was found to be highest because of the lower number of points. Bias in locating points was felt to be smallest with the point-quarter

method because it is harder to locate four trees in a preferential manner than one or two trees.

83. Conner and Day (1976), in a Louisiana swamp, and Schlesinger (1978), in the Okefenokee Cypress swamp in Georgia, sampled the tree stratum using the point-centered quarter method. Monk and his colleagues (Monk and Brown, 1965; Monk and McGinnis, 1965; Monk, 1966) have used point-quarter/quadrat combinations in cypress dome, mixed swamps, and bayheads in north-central Florida. In each study, trees and shrubs were sampled with the point-quarter method, and seedlings, shrubs, and herbs were sampled in 0.5-m by 2.0-m rectangular quadrats.

84. Marks and Harcombe (1975) used 20 to 25 point-quarter points per stand in coastal plain forests of southeast Texas. A sample number of 15 to 20 points was determined to have a mean distance variance of less than 15 percent with a 95-percent confidence interval. Shrubs and saplings were sampled for density in a 5-m by 5-m quadrat at each point (total sample area about 500 m<sup>2</sup>). Grigal and Ohmann (1975) have used a sample size of 20 point-quarter points for trees, 4-m<sup>2</sup> circular plots for shrubs, and 0.18-m<sup>2</sup> rectangular plots for herbs in Minnesota forests.

85. The random pairs method has been used in Wisconsin by Brown and Curtis (1952), Bray and Curtis (1957), and Ward (1968). Each research team used 40 points for a sample size of 80 distances. Ward used the point-quarter method as well for sampling, while Brown and Curtis used the four closest saplings method. Each used 1-m<sup>2</sup> quadrats at 20 points (20-m<sup>2</sup> sample area) for herb density.

#### Other Methods

86. Belt transects are 2-dimensional sampling units with specified boundaries that must be laid out in the stand.

Essentially, they are very long, rectangular quadrats simply called "strips" or transects. This method usually is used for trees and for sparse, shrubby undergrowth that can be counted conveniently. A typical belt transect is 0.25 m to 5 m wide on either side of a center line running through a stand. This method allows for calculation of frequency, basal area, and density of each species per unit area.

87. Woodin and Lindsey (1954) and Lindsey (1955) introduced a method called the "line-strip method," which is essentially a combination of the line-intercept method for cover and a very long, narrow rectangular quadrat for density, basal area, and frequency sampling. Woodin and Lindsey refrained from calling this a belt-transect method since it is not necessarily a straight line, several strips are used at each station, and they do not necessarily go across or transect a zone or stand. The method is recommended by Lindsey (1955) because of the value of line-intercept cover measurements for dominance determination, the superiority of long, narrow quadrats for both homogeneous and clustered populations, the speed of sampling, and suitability for statistical evaluations.

88. The line-strip method consists of a surveyed line placed randomly, with the strip being laid out on either side of the transect line. Length and width can vary in response to pattern, density, and physiognomy of the vegetation.

89. Lindsey (1955) tested the line-strip method against census data in three coniferous forest types. He found that the 20-foot strip was somewhat wider than needed for conifers and less than needed for deciduous species. Once again, the method was found to be inadequate for accurate results with minor species within the area sampled, but was suitable for important species. Lindsey (1955) showed that coverage of 15 percent of the stand area probably would be required for complex communities.

90. Quantitative quadrat sampling techniques with slight variations have been used by other investigators for sampling salt

marshes. Bolen (1964), in his studies of inland salt marsh vegetation in western Utah, analyzed 225 rectangular plots along line transects to determine the density and frequency of marsh species. Brereton (1971) studied aggregations of individuals in salt marshes near the North Wales coast using contiguous quadrats along three belt transects. Cover was determined using the point-quadrat method with 10 points at 1-centimeter (cm) intervals along a line in each quadrat. Flowers (1973) and Eleuterius (1972) have used density or list-count belt transects in salt marshes of Maryland and Mississippi, respectively.

91. Lindsey et al. (1958) compared a census to 0.2-, 0.1-, 0.04-, and 0.002-acre square quadrats; 0.1-, 0.04-, and 0.002-acre circular quadrats measured with a rangefinder; 0.2-acre strips; point-quarter method; full variable radius; and a variable radius-circular quadrat combination. The objective was to determine the most efficient method for obtaining data with less than a 15-percent SEM. The best methods were ranked in the following order, along with relative field time:

- a. Variable radius-circular quadrat--2.04 hours.
- b. 0.1-acre rangefinder circular plots--3.41 hours.
- c. 0.2-acre strip--3.65 hours.
- d. Full variable radius--3.66 hours.
- e. Point-quarter--4.36 hours.
- f. 0.2-acre square plot--5.17 hours.
- g. 0.1-acre square plot--5.81 hours.
- h. 0.002-acre circular plot--6.85 hours.
- i. 0.002-acre square plot--9.84 hours.

92. Investigators seem to have particular problems with riparian communities and resort to the use of multiple methods in river floodplains. Wistendahl (1958), in a study of the Raritan River, used 200-m to 400-m belt transects parallel to the river for old field forests. Nested quadrats of 2 m by 10 m (trees), 1 m by 10 m (saplings), and 0.5 m by 2 m (herbs) were analyzed for

density. Sample areas per stand were thus 400 m<sup>2</sup> to 800 m<sup>2</sup> for trees, 200 m<sup>2</sup> to 400 m<sup>2</sup> for saplings, and 20 m<sup>2</sup> to 40 m<sup>2</sup> for herbs. Cover in the floodplain forest was analyzed separately by line-intercept perpendicular to the river. Finally, a combination of quadrats and line-intercept was used for riverbank vegetation.

93. In a study of the Wabash and Tippecanoe River floodplains, Lindsey et al. (1961) used four separate methods:

- a. 0.0025-acre quadrats placed randomly on the floodplain forests and along belt transects in early successional areas.
- b. Measurement of the distance range of each species from average water level.
- c. The 0.20-acre strip (121.2 m by 6.7 m) method on linear stands.
- d. Line-strip sampling by 15.2-m intervals for density and sighting rod for cover.

94. Johnson et al. (1976) used the point-quarter method for trees with 40 points along transects perpendicular to a river. Saplings were sampled with the line-strip method using 1.2-m by 7.6-m intervals for density measurements. Seedlings were sampled with 20 1-m<sup>2</sup> circular plots per stand.

#### Preliminary Conclusions About Suitability of Methods

95. A review of the literature led to a number of preliminary conclusions which appear to follow from the results of the studies cited. Although, in time, some may need to be altered due to the inclusion of new data sources, it is likely that they will continue to apply to most field sampling situations. Most of the studies comparing field accuracy and efficiency had been made in relatively simple or easily sampled communities and had not been adequately tested in the specific communities of southern

Louisiana. However, the few studies applying these methods in wetlands and southern communities appear to support the validity of the conclusions. The following conclusions have been made:

- a. The species-area curve method is not a statistically valid or appropriate criterion for sample size evaluation with quantitative methods. It may, however, be utilized as an approximate guide for the lower limits of minimal area for quantitative samples. With adequate prior data on a community, it may be possible to equate the curve to a statistical parameter.
- b. The SEM as a ratio of the mean is a satisfactory criterion for evaluating accuracy of quantitative methods. The SEM for a particular sample size can be calculated and can be estimated in the field by the running mean value.
- c. A 15-percent SEM for the total population and most abundant species usually is attainable in the field with reasonable effort. Efficiencies of various methods can be compared on the basis of effort or time needed to meet a predetermined level for the SEM.
- d. Comparisons of efficiencies should take into account other factors such as preparation effort, computational effort, equipment needs, required level of training, and amount of information yielded.
- e. Although satisfactory levels of the SEM may be met for abundant species, the levels for all but the top three to five species will probably be inadequate.
- f. Subjective estimations of quantitative values seem to have value and high efficiencies, but are less defensible, statistically. Presence or absence data can, however, be used with validity to establish statistical correlations of associated species.

- g. Loop-frequency and crown-diameter methods are inferior to line-intercept and point-intercept methods as measures of cover.
- h. Line-intercept and point-intercept methods are reproducible and yield data with approximately equal accuracy.
- i. Crown cover is a better estimate of dominance than is stem basal area alone.
- j. For sampling large herbaceous areas, the cover class quadrat estimation seems to yield results comparable to those using 5-foot line-intercepts at identical points. However, the line-intercept may be preferred because it is statistically defensible and less subject to errors due to bias and lack of training.
- k. Biomass is an accurate measure of dominance, but is inordinately time-consuming (low efficiency) and not reproducible on a seasonal basis.
- l. Of the distance measures, all can give an adequate accuracy of less than 10-percent SEM with adequate sampling effort, usually about 100 to 150 trees. The point-centered quarter method is the most efficient and reaches adequate size with 20 to 25 points.
- m. Because of highest efficiency and lowest inherent subjective bias, the point-centered quarter method is the preferred distance method.
- n. For basal area, the variable radius method is the most efficient. It is less valid for density and frequency; for these determinations, it should be used in conjunction with a quadrat technique.
- o. Systematic, random, and stratified random placement of quadrats have similar levels of accuracy, but the stratified random approach is preferred because it is always somewhat more accurate than the random, and it is easier to evaluate statistically than the systematic placement.
- p. Use of rectangular or circular plots is superior in accuracy to the use of square plots; with reasonable plot size, i.e., less than 0.1 acre, it is more efficient.

- q. In order to meet the 15-percent SEM accuracy level, total quadrat area as a percentage of total stand area may be in the range of 15 to 100 percent for trees, 2 to 40 percent for shrubs and understory, and 1 to 5 percent for herbs.
- r. The line-strip method usually requires a sample area of about 15 percent of total stand area to reach the 15-percent SEM level. Six to ten 7-m by 200-m strips are generally required, but strip width may be greater with broad-crowned deciduous species, and narrower with narrow-crowned coniferous species.

96. The literature on which these conclusions are based provides a substantial data base which can document the elimination of several potential methods from field sampling consideration on the basis of inefficiency, inaccuracy, or lack of statistical validity. On the basis of these conclusions, several of the most suitable remaining methods were selected from Phase I field evaluations. The SEM criterion was also selected as a primary tool for Phase I evaluation.

PART II: PHASE I STUDY--EVALUATION OF  
FIELD SAMPLING METHODS

Description of Sites

97. Three study sites were included in the Phase I sampling program in order to evaluate the selected field sampling methods in wetlands for delineating the different physiognomic characteristics or dominant life forms found in the study area. Each study site consisted of a portion of a relatively undisturbed wetland grading through a transitional zone into the adjacent uplands community. Appendix A contains a species list of all taxa observed in the study sites. Most, but not all, taxa observed in the study sites were encountered in the quantitative sampling summarized as Appendices B and C. The two marsh sites selected for Phase I were a brackish marsh and an intermediate (but shrub-dominated) marsh, both of which graded directly into forests through shrub-dominated transition zones. Within the study area, no sites could be located in which smooth cordgrass (Spartina alterniflora)-dominated saline marsh graded directly into upland areas and which also met the criteria for site selection. Other marsh types which had been described in the literature (Penfound and Hathaway, 1938; Penfound, 1952) as being present in this region, but for which suitable study sites could not be located, included broadleaf cattail- and giant bulrush-dominated deep fresh marshes, and sawgrass or horned grass (Rhyncospora)-dominated shallow marshes.

Site A (brackish marsh)

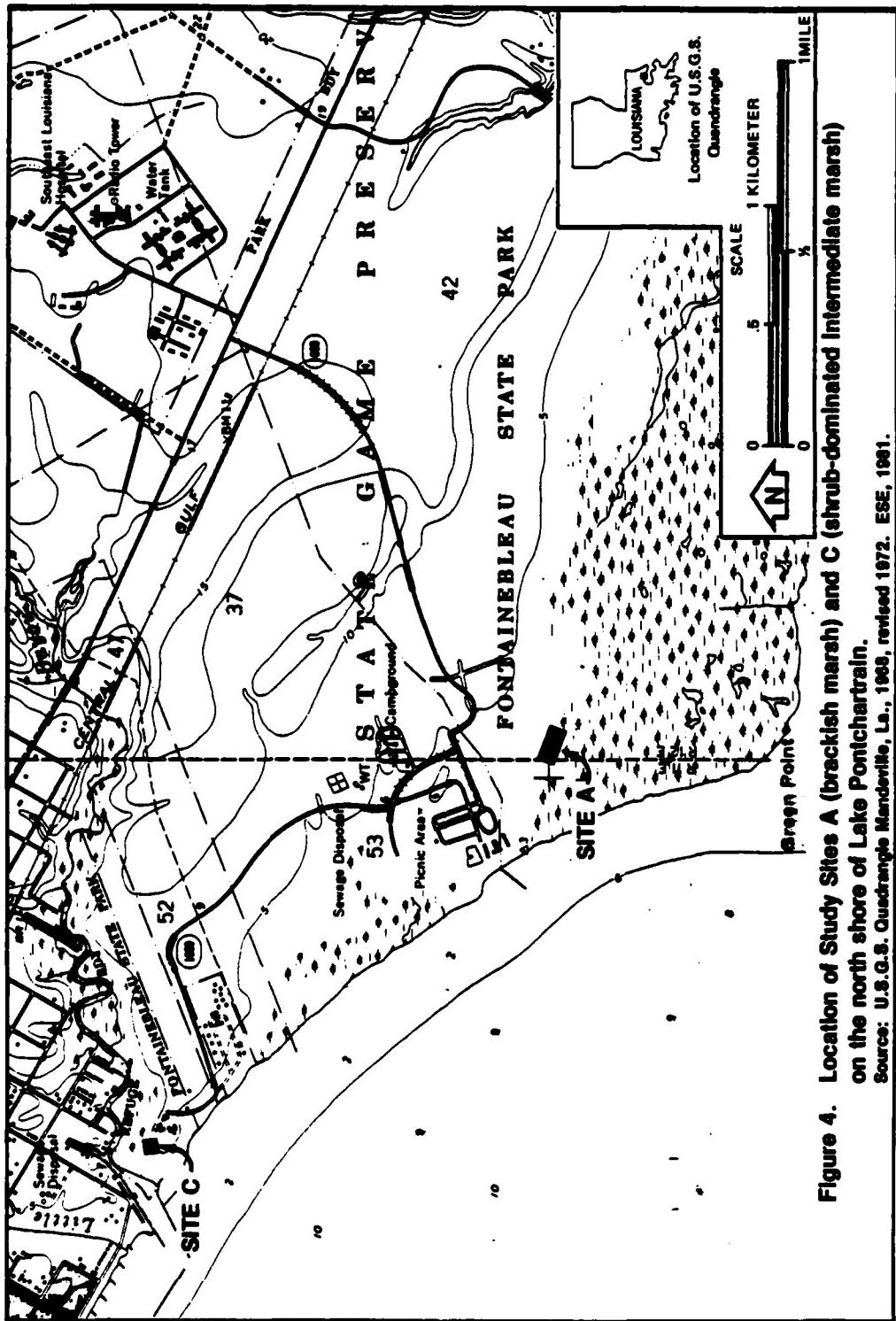
98. Site A was chosen as representative of the transition from a graminoid-dominated marsh wetland into a mature stand of the dominant oak-pine forest of the study area. Site A was located within Fontainebleau State Park in St. Tammany Parish on

the north shore of Lake Pontchartrain (Figure 4). A 100-m by 80-m (330-ft by 264-ft) study site was established at the marsh-forest boundary adjacent to the western edge of Section 42, T8S, R12E, and about 400 m (1,320 ft) east of the bath house at the park.

99. The shoreline of the lake at this location has a south-southwest exposure, and the edge of the marsh, as well as the topographic contour, is oriented along a fairly straight southeast-northwest axis. The entire study site has an elevation of less than 1.5 m (5 ft) and a slope of less than 1 percent.

100. The marsh has a width of about 1 kilometer (km), the outer edge of which is partially screened from the lake by a low (0.3-m) berm. During the year prior to this study, the U.S. Army Corps of Engineers, New Orleans District, was engaged in a study of natural and artificial means of stabilizing this berm. Behind the protection of this berm, the normal summer tidal range is low. Tidal creeks are rare and water depth is seldom more than 0.5 m (1.7 ft). Within the boundary of the study site, maximum water depth during the study period was 0.2 m (0.6 ft); minimum depth in the deepest portions was 0.1 m (0.3 ft). From the rear of the berm to a point within about 10 m (33 ft) of the transitional zone, the marsh consisted almost entirely of saltmeadow cordgrass (Spartina patens). Black rush (Juncus romarianus) and morning glory (Ipomoea sagittata) were the only other species found within the brackish marsh of this site. Herbaceous cover in the marsh was about 90 percent.

101. The transition zone of the marsh (the area extending from the lowest limits of upland species to the upper limits of wetland species) generally was dominated by shrubs (43-percent cover). The dominant shrubs were groundsel (Baccharis halimifolia), wax myrtle (Myrica cerifera), ladies eardrops (Brunnichia cirrhosa), blue palm (Sabal minor), and marsh elder (Iva frutescens). Herbs, in addition to saltmeadow cordgrass, included alligatorweed (Alternanthera philoxeroides), black rush,



**Figure 4. Location of Study Sites A (shrub marsh) and C (shrub-dominated intermediate marsh) on the north shore of Lake Pontchartrain.**

**Source:** U.S.G.S. Quadrangle Mandeville, La., 1963, revised 1972. ESE, 1991.

saltgrass, and switchgrass (Panicum virgatum). The shrub canopy was about 2 to 3 m in height.

102. The forest community was older growth oak-pine with several other species sharing equal or greater dominance. Loblolly pine, live oak, water oak, and sweetgum dominate the overstory, while yaupon (Ilex vomitoria) and wax myrtle dominate the understory strata. The shrub stratum was well-developed (60- to 80-percent cover), with yaupon as the dominant species. Ladies eardrops were common in both shrub and herb strata, with greenbriar (Smilax spp.) and other vines comprising most of the sparse (5- to 10-percent cover) herb strata. There appeared to be a difference or zonation within the structure of the area defined as upland, which occurred about 20 m above the end of the transition zone. Above this point, both tree and shrub cover appeared to increase. Several species such as red buckeye (Aesculus pavia) reached their lowest limit at this point. The lower of these two 20-m (66-ft) wide zones was labeled "Upland Zone," and the upper of the two was labeled the "Second Upland Zone."

103. The forest was relatively free of recent disturbance. Trunk diameters ranged up to 60 cm [24 inches (in)] for loblolly pine, 52 cm (20 in) for live oak, and 72 cm (28 in) for sweetgum. The outer edge of the oak-pine forest occurred where a small berm or natural levee only 6 to 10 cm in height ran along the marsh edge. Live oak and loblolly pine were the only large trees found in this zone. Such a pattern indicates that factors other than elevation and hydroperiod may be influencing zonation at this site. The influence of saline spray or ground water may well be a major determinant of species distribution.

104. The transition zone at this site appeared to have two subzones, the lower of which had fewer trees, less cover, and greater signs of overwash or standing water. It appeared that this portion probably is inundated on a regular basis by storms or high tide in most years, whereas the upper zone may experience

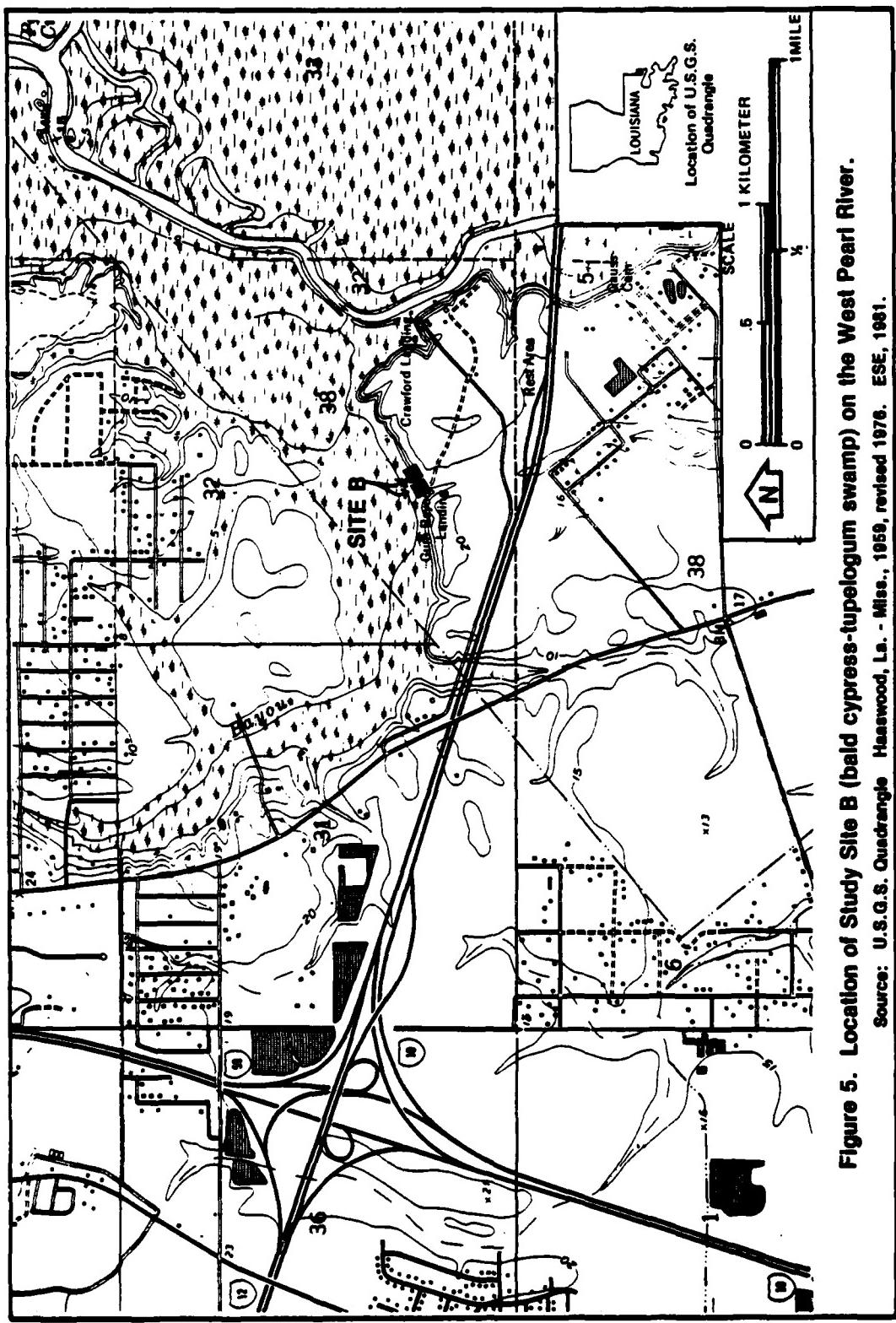
flooding only in more extreme years. This interpretation was supported when the minor storm, Hurricane Bob, passed directly over the site during the sampling period. The high water mark, as predicted, was at the upper end of the lower zone. Extensive damage occurred in the upper zone due to wind effects. The area previously designated as upland appeared to have been protected, and suffered virtually no damage.

Site B (bald cypress-tupelo-gum swamp)

105. The second study area was located along the west channel of the Pearl River about 3 km (2 miles) east of Slidell (Figure 5). This site (Sec. 38, T8S, R15E), on the southern bank of Gum Bayou, occupied a relatively straight, north-facing, 5-percent slope, with elevations ranging from 1 m (3.3 ft) to 5 m (16.5 ft) above msl. Beyond both the east and west boundaries of the site, the landform became less even and was dissected by erosional features and ephemeral tributaries.

106. Because of the presence of an apparently unused dirt road and launching ramp (Gum Bayou Landing), the study site was divided into two 50-m (165-ft) by 60-m (198-ft) units separated by the width of the disturbed area. Slope, exposure, and vegetation were consistent in both units.

107. The lowest third of the site was a bald cypress-tupelo-gum swamp. Although the mean and maximum size [21.6 cm and 51 cm diameter at breast height (dbh), respectively] of the bald cypress trees was similar to that of gum, their lower density resulted in a low importance value (IV). Swamp blackgum and water tupelo shared dominance almost equally and ranged in diameter to 64 cm and 53 cm dbh, respectively. Canopy cover was essentially 100 percent. Understory trees and shrubs included titi (Cyrilla racemiflora), Carolina ash (Fraxinus caroliniana), buttonbush, and common winterberry (Ilex verticillata).



**Figure 5. Location of Study Site B (bald cypress-tupelo-gum swamp) on the West Pearl River.**

Source: U.S.G.S. Quadrangle Hailewood, La. - Miss., 1959, revised 1976. ESE, 1981.

108. Normal water depths in the sampling site at the time of sampling ranged from 0 cm to a maximum of 92 cm (36 in) in the deepest zone. Duckweed (Lemna minor) covered about 90 percent of the water surface. Coontail (Ceratophyllum demersum) and greenbriar were also present, as was cane (Arundinaria gigantea) along the margins. Within 12 hours of the passing of Hurricane Bob (July 15, 1979), water levels had risen from 92 cm (36 in) to about 115 cm (45 in). Signs of dried coontail and water marks indicated that maximum water levels in spring of 1979 had reached 140 cm (58 in).

109. The central or transitional portion of the site contained species from both upland and wetland zones. Swamp blackgum, water tupelo, spruce pine, and water oak were common in the overstory. Common winterberry, titi, common sweetleaf (Symplocos tinctoria), and arrowwood (Viburnum dentatum) were dominant shrub species. Common herbs included partridge berry (Mitchella repens), cane, and elephant's-foot (Elephantopus tomentosus).

110. The upland portion of the site graded into an earlier successional stage of a previously cleared area. Although density and cover were similar to that of the transition zone, species composition differed and mean tree size was somewhat lower. Live oak, willow oak, and spruce pine were dominant, with common sweetleaf, sparkleberry (Vaccinium arboreum), and ironwood common in both tree and shrub strata. Partridge berry comprised the only significant herbaceous cover in this zone. Shrub cover in both zones was about 35 percent and herb cover was about 1 percent in this heavily shaded community.

#### Site C (shrub-dominated intermediate marsh)

111. The third site was also in Fontainebleau State Park (Sec. 51, T8S, R11E), on the east shore of Bayou Castine. This

site, directly across the bayou from the town of Mandeville (Figure 4), differed substantially from Site A in physical appearance and species composition. Site C was characterized by a low elevational gradient (2.5 percent slope), and a relatively high clay content in the sandy upland soils. A 100-m (330-ft) wide marsh zone extended between the shore and the edge of the channel. Although water depth in the marsh at the edge of the channel may be up to 40 cm (16 in), it ranged from only 0 to 10 cm (4 in) in the study site during sampling.

112. Although less than 2 km (1.3 miles) from Site A, this site had a lower salinity due to the freshwater influx from Bayou Castine. Consequently, this marsh had a richer flora (16 species at Site C versus 3 species at Site A). Saltmeadow cordgrass remained the dominant species, but alligatorweed, spikerush, and bulbtongue were major subdominants. Additional species in Site C marsh were knotweed (Polygonum hydropiperoides), morning glory, butterfly pea (Clitoria mariana), rattlesnake master, rattlebox (Sesbania exaltata), carpet weed (Mollugo verticillata), and sedge (Cyperus virens).

113. Shrubs were dominant in wetland Site C as compared to Site A, with an estimated cover of about 50 percent. Groundsel, marsh elder, blue palm, wax myrtle, and rose (Rosa bracteata) all occurred. Most shrubs in this zone were small, scattered individuals, with heights of 1 to 2 m, indicating an early stage of shrub succession.

114. The transitional zone was similar to that of Site A, in that shrubs were again dominant. Density and cover (over 65 percent) were greater here, probably in response to the more sheltered and less saline site location. Marsh elder, blue palm, groundsel, chinese tallowtree (Sapium sebiferum), rose, and blackberry (Rubus betulifolius) were prevalent. Ground cover composition was more similar to that of the wetland than of the upland zone. Tree cover, however, was more like that of the

upland zone. Loblolly pine, live oak, and bitternut hickory (Carya cordiformis) were present, as well as wax myrtle and black willow.

115. The forest adjacent to the site was bordered by a state park group camp which was about 50 m (165 ft) upgradient. Considerable disturbance has resulted, causing a low shrub cover (26-percent), and an open, well-developed herb strata (45-percent cover). The introduced St. Augustine grass (Stenotaphrum secundatum) dominated the herb layer, with panic grasses (Panicum spp.), ladies eardrops, trumpet creeper (Campsis radicans), and rattlesnake master (Eryngium yuccifolium) also common.

116. Trees at this site were also younger than at Site A, and cut stumps of pines were present. Maximum trunk diameters at this site were about 24 cm (9.5 in) to 51 cm (20 in), compared to 72 cm (28 in) at Site A.

117. Site C differed from Site A not only in the relative dominance of each strata, but also in the changes in pattern within strata with the progression from wetland to upland.

#### Phase I Methods

##### Selection of sampling sites

118. In order to be considered as a potential sampling site, each location was originally intended to meet certain criteria such as: (1) having characteristics of community types of the region; (2) providing a gradient from wetland to upland zones with a minimal degree of disturbance; (3) providing a stand size of largely homogeneous vegetation sufficient for use with each sampling method; and (4) being very likely to remain in its natural state.

119. Locating suitable wetland sites presented few problems; however, locating such sites with minimally disturbed uplands in

proximity to the desired wetland area proved to be difficult. Because of a lack of suitable undisturbed uplands, several desirable wetland communities could not be sampled, and compromises in the degree of upland disturbance and future protection had to be made, such as at Site C, in which the upland zone had been disturbed.

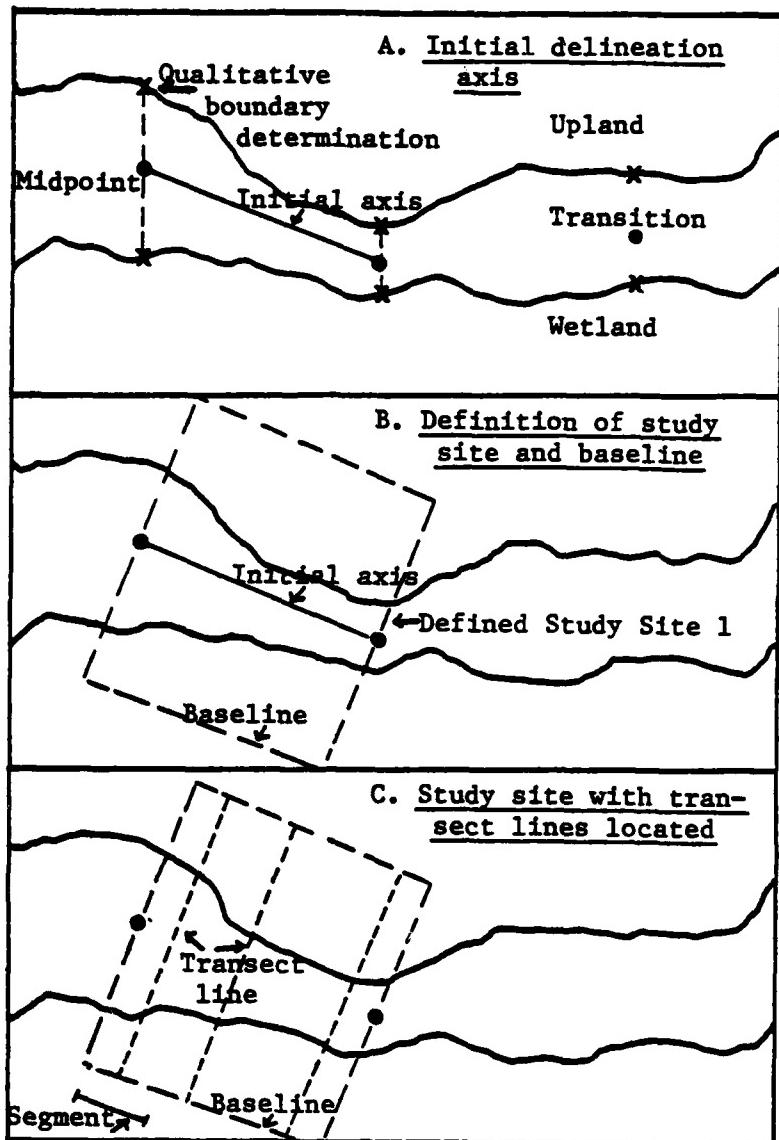
120. Selected sites had to extend a minimum of 20 m into both upland and wetland zones and have sufficient lateral dimension to accommodate use of all selected methods. Sampling site sizes of at least 100 m by 60 m for forested stands and 30 m by 60 m for stands dominated by herbaceous vegetation were required for the sampling program.

Definition of site boundaries and sampling design

121. The Phase I sampling design was similar to that of Reiners (1972) for studying community types occurring in sequence along a gradual slope. The study sites selected contained essentially linear and parallel contour lines. The transitional zone and the upland and wetland boundaries tended to follow the same pattern as the contour lines, thus permitting the use of a grid system for defining the study site and the various communities or zones within each site.

122. To establish the grid with the optimal location and orientation, each site was first qualitatively surveyed to estimate the degree of homogeneity, the relevant characteristics of the site, and the probable location of the transitional zone. Points that appeared to represent the midpoints of the transition zone were then selected near each end of the site (Figure 6A). A line was marked connecting these points and running approximately parallel to the vegetational contours.

123. A recommended sampling plan for sampling all strata is presented in Figure 6. When total density and cover are sampled



**Figure 6.** Three stages of a recommended process for establishing sampling transects across transitional gradients

to an SEM of 15 percent for trees and 10 percent for shrubs and herbs, the resultant community description for species composition within a zone should be within 80 percent of the true composition as expressed on the ISBC.

124. Figure 6 illustrates a recommended method for initiating the sampling plan at a site containing a transition zone. The method is similar to that used in Phase I of this study, in which the approximate upper and lower ends of the transition zone are qualitatively located. The midpoint of these limits is connected (Figure 6A) to form the initial axis of the sampling area. A baseline is identified within the wetland zone and parallel to the initial axis (Figure 6B). The baseline is then divided into equal segments and transects are located randomly within segments, running perpendicularly from the baseline to the upland zone (Figure 6C).

125. Three to five perpendicular lines per site were extended up-gradient and down-gradient from this center line in a stratified random manner. Each line was used for the line-intercept cover method for determining presence and absence of species (association analysis) at 1-m intervals along this gradient. The lines were extended sufficiently into the wetland and upland zones to ensure that at least 20 m of each zone were sampled. Herb, shrub, and tree strata were sampled along each line.

126. Results of the line-intercept sampling were used to redefine the orientation of the central axis as needed, to ensure that the axis ran through the middle of the transitional zone parallel to the zonation. A grid system was marked out centered on this central line and extending approximately 20 m into the upland and wetland zones. This arrangement permitted equal sampling intensity in upland and wetland communities.

127. The resulting study area was separated into 10-m by 10-m units or quadrats. The direction parallel to the presumed

zone boundaries was designated the x-axis of the grid, and the direction perpendicular to the boundaries was designated the y-axis, with distance units beginning at the lower left corner. At Site A (brackish marsh), the sampling area consisted of an 80-m (y-axis) by 100-m (x-axis) area. At Site B (gum swamp), the sampling area was 60-m (y-axis) by 100-m (x-axis), and at Site C (shrub swamp), the area was 60-m (x-axis) by 30-m (y-axis). Each 10-m by 10-m quadrat was marked as a basic grid unit.

128. Subsequent sampling at Site A indicated an area of marsh incursion into a portion of the transitional zone which resulted in a nonhomogeneous distribution of herbaceous vegetation. Subsequent sampling of the herb strata was limited to the 80-m by 50-m eastern half of the site.

129. An apparently unused dirt road and landing were found in the center of Site B. As a result, the sampling site was split into two 60-m by 50-m units separated by a distance of 10 m to avoid the disturbed area.

130. Therefore, at each site, there were two 10-m-wide bands of quadrats in both the upland and wetland zones. At Sites B and C, the qualitatively defined transitional area was contained within two 10-m-wide bands. At Site A, the transitional zone appeared to be contained within two 10-m-wide bands. However, at this site, there appeared to be sufficient gradation of species composition to include a separate 20-m-wide band (upland Zone 1) to be treated as distinct from both the transition zone and the true upland zone (upland Zone 2).

131. For this study, the use of each of these bands as 20-m-wide "sampling zones" was done only to aid in the comparison of methods and to allow statistical evaluation of methods in several defined portions of the wetland-upland gradient. The "sampling zones" or bands were not meant to represent a final delineation of the transition zone limits.

Quantitative sampling method for trees

132. The tree (overstory) stratum was sampled extensively only in Sites A and B. Site C did not contain sufficient area for valid tree sampling. All trees in Site C were tallied, but no further analysis was made.

133. Table 3 lists the sampling methods employed for trees at these sites. These methods were selected as the most suitable and most representative of the many techniques reviewed during the literature phase of the study.

134. The sampling design was based on the grid system established for each site. The 10-m by 10-m, 100-m<sup>2</sup> circular, and 200-m<sup>2</sup> circular quadrats, and the variable radius method points (Mueller-Dombois and Ellenberg, 1974) were centered on each of the 10-m by 10-m grid units. The 10-m by 20-m rectangular quadrats were formed by combining or nesting adjacent 10-m by 10-m grid units. Each grid unit was bisected parallel to the zonation to form two 5-m by 10-m sub-units. Adjacent sub-units were combined to form the 5-m by 20-m quadrats.

135. The sampling design thus permitted a total of 20 quadrats in each 20-m-wide zone for the 100-m<sup>2</sup> square quadrats and all circular quadrats. Thus, ten 10-m by 20-m quadrats were formed in each zone. Rectangular quadrats (200 m<sup>2</sup>) were oriented both parallel and perpendicular to site contours.

136. For each method, trees were defined as all living stems measuring over 5.1 cm (2.0 in) at dbh with a height of 1.2 m (4 feet) or more.

137. Quadrat methods. All stems meeting the above definition were recorded by species and dbh for each 5-m by 10-m half of each grid unit. These data were later recombined to form the various square and rectangular quadrats. Circular quadrats were established with centers at the center of each grid unit, and

Table 3  
Listing of Tree-Sampling Methods Used  
at Each Phase I Sampling Site

<u>Site</u>	<u>Methods</u>
A	Total census 10-m x 10-m quadrats 5-m x 20-m quadrats (parallel to zones) 10-m x 20-m quadrats (parallel to zones) 10-m x 20-m quadrats (perpendicular to zones) 100-m <sup>2</sup> circular quadrats 200-m <sup>2</sup> circular quadrats Point-centered quarter distance method Bitterlich variable radius distance method Qualitative cover estimates within 10-m x 10-m quadrats Modified line-intercept
B	Total census 10-m x 10-m quadrats 5-m x 20-m quadrats (parallel to zones) 10-m x 20-m quadrats (parallel to zones) 10-m x 20-m quadrats (perpendicular to zones) 100-m <sup>2</sup> circular quadrats 200-m <sup>2</sup> circular quadrats Point-centered quarter distance method Wandering quarter distance method Bitterlich variable radius distance method Qualitative cover estimates within 10-m x 10-m quadrats Modified line-intercept
C	Total census Location mapping Qualitative cover estimates within 10-m x 10-m quadrats

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Source: ESE, 1981.

the limits of the circle were determined with a Ranging 120° optical rangefinder following the method of Lindsey et al. (1958). Species and dbh for all stems within a 5.64-m radius for the 100-m<sup>2</sup> circle and an 8.00-m radius for the 200-m<sup>2</sup> circle were recorded. Area measurements for each circle were determined to be within ±5 percent of the desired area using the optical rangefinder and probably within ±2 percent for the cumulative sample area.

138. Square and rectangular quadrats were surveyed and marked as part of the grid system layout. The most rapid means of establishing this grid system consisted of a two-person team for laying out the latitudinal and longitudinal lines and marking the 10-m intervals. A third person followed the line and recorded the x and y coordinates of each corner point. The third person also laid out twine lines to mark the units and adjusted corner points as necessary. Each resulting quadrat was estimated to be within ±11 percent of desired value. This estimate is based on the fact that each grid was within a length range of 10.0 ± 0.5 m on all sides.

139. An attempt was made to lay out the square quadrats by establishing the half-diagonals of the quadrat, using the method of Lindsey et al. (1958). However, this method was not satisfactory due to: (1) the effect of the heavy shrub cover on visibility; (2) the relatively small size of the quadrats; and (3) the number of quadrats to be established. While the half-diagonal method may be better suited for larger plots in more open stands, it resulted in lower overall accuracy in establishing quadrat size and shape for these study sites.

140. A comparison was made of the time requirement for establishing quadrats in each fashion. The average time required per quadrat based on a sample size of 60 quadrats per site was found to be roughly equivalent for both methods (0.48 manhour for

the grid and 0.46 manhour for the half-diagonal method on Phase I sites).

141. All quadrat measurements were made with two-person teams. One person served as the recorder, while the second person identified and measured each tree. For circular quadrats, the recorder used the rangefinder to identify which trees were in the quadrat, while the second person measured dbh.

142. The Bitterlich variable radius method was used in conjunction with circular quadrats as an alternative method for computing basal area, thereby eliminating the need to measure the diameter of each tree in the quadrat. An angle gage or "Bitterlich stick" was used instead of a prism due to the low light condition of the selected stands. This instrument, introduced by Bitterlich (1948), consisted of an 84.6-cm (33-in) rounded sighting stick with a 2.56-cm (1-in) diameter wood cross-piece mounted at one end. The resulting 1:33 ratio of cross-piece width to sighting length permitted an equivalent sighting angle of 1°45' with a basal area factor of 10 (Mueller-Dombois and Ellenberg, 1974). In sites with better light conditions, a clear, glass prism with identical angle basal area factors could be substituted for the stick angle gage.

143. When using the gage, the observer stood at the center of each circular quadrat and held the gage to his eye, sighting along the gage toward the cross-piece. The gage was pointed toward each tree visible within a circle surrounding the point. The presence and species of any trees appearing wider than the cross-piece was recorded. The number of trees recorded was directly converted to basal area ( $\text{ft}^2$ ) per acre by multiplying by the conversion factor of ten. All Bitterlich measurements were made and recorded by a single observer.

144. Distance methods. The point-centered quarter (point-quarter) method of Cottam and Curtis (1956) also was used

to sample density and basal area in trees. In this method, four quarter-circle arcs were established at a point formed by the intersection of two lines. One line was a selected compass direction and the second was a line perpendicular to the compass direction through the point. The nearest tree within each of the four quarters was identified, and the distance from the point to the midpoint of the base of the nearest tree was recorded, along with species and dbh.

145. Points in each 20-m sampling zone were located along a line through the center of each grid unit and parallel to the zones. Ten points were established along these lines through each of the 10 m belts of each zone. A total of 20 points and 80 trees was sampled in each zone. One point was randomly located in each 10-m segment of the line, thereby effecting a stratified random sampling design for each zone.

146. This sampling design was flawed in that some individuals occasionally were counted twice. Although theoretically this duplication could affect the statistical validity of the data, it is believed that the basic data and conclusions were not significantly altered. Less than 10 percent of the trees in any sample were duplicate samples.

147. The point-quarter method generally required two people--one to record and locate sample points, and one person to measure distances and diameters.

148. The wandering quarter method (Catana, 1963) compensates somewhat for some of the limitations of the point-quarter method. This method was introduced at Site B after the space requirement limitation of the point-quarter method became apparent.

149. The original Catana method utilized four lines per stand in perpendicular groups of two. To define and remain within zones, this study has utilized only two lines parallel to the zones and within each zone. Each line began at the origin of the point-quarter line. At this point, a quarter was established with

the center line of the quarter parallel to the band. The distance from the origin to the nearest tree in this quarter was measured, along with the species and dbh. The first tree became the vector of a second quarter laid out in the same compass direction as the first, and the distance to the nearest tree in this quarter was measured. A total of 25 to 30 trees could be measured within the 100-m width of the site. In general, each line remained within a lateral distance of 5 m from the original line and thus remained within each 10-m-wide band. Wandering quarter sampling was done by a single individual.

150. Cover methods. Tree canopy cover of each species was estimated for each 10-m by 10-m quadrat using a visual estimation of the percent of ground area covered by a vertical projection of the canopy. For cover estimates greater than 5 percent, the estimates were made in 5-percent increments. For estimates of under 5 percent, the estimates were made to the nearest 1 percent. All cover estimates were made by the recorder member of the two-person team doing the quadrat sampling.

151. Cover of the tree canopy also was evaluated by a modification of the line-intercept method of Canfield (1941). In the ESE study, the association analysis transects laid out for the initial determination of site zonation also were used for line-intercept, so that sample size consisted of three to five transects per site. Each transect was divided into 1-m segments such that 20 segments on each transect occurred in each zone. Cover was estimated by first recording the presence of canopy cover overlap for each species within a segment. Frequency of occurrence in each block of five segments was used as an approximation of cover value. The vertical projection of canopy cover was determined by sighting along a 3-m sighting rod held vertically from the midpoint of each segment. The use of 1-m segments provided a sufficient margin to allow for errors in the vertical projection of the rod. It was believed that smaller segment intervals would

not allow a sufficient level of confidence with this method. The use of more sophisticated cover sights or sighting levels can increase the confidence levels of the line-intercept method, but the necessary equipment and time for preparation increase proportionally. All line-intercept observations were made by single individuals.

Quantitative sampling methods for shrubs

152. The shrub stratum was sampled in Sites A, B, and C, with most emphasis on Site C (the shrub-dominated wetland). Table 4 lists the shrub sampling methods selected from the literature as being the most accurate and useful for this stratum.

153. Shrubs were defined as all stems having a stem diameter of more than 2 cm (0.78 in) at a height of 10 cm from the base, a dbh of less than 5.1 cm (2.0 in), and a height of over 61 cm (24 in). The sampling design for shrubs was similar to that for trees and was also keyed to the grid pattern.

154. All 4-m by 4-m quadrats were nested within the 10-m by 10-m grid units. At Site C, each 10-m by 10-m grid unit was divided into four 5-m by 5-m quadrats. The summation of these 25-m<sup>2</sup> quadrats of Site C represents a total shrub census for that site. The other sites were not censused. Sampling with the 4-m by 4-m quadrats covered 10 percent of the total area of each site.

155. The point-centered quarter method was used for shrubs in a manner similar to that used for trees, except that stem diameter was measured at a height of 10 cm. At Sites A and B, the same points were used for shrubs as for trees. Since shrubs were spaced more closely together than trees, no problems were encountered with sampling the same individuals twice. At Site C, the ten points on each line were randomly selected to fit within the 30-m width of the site. At this point, density-duplication

Table 4  
Listing of Shrub-Sampling Methods Used  
at Each Phase I Sampling Site

<u>Site</u>	<u>Methods</u>
A	4-m x 4-m quadrats Point-centered quarter distance method Modified line-intercept
B	4-m x 4-m quadrats Point-centered quarter distance method Modified line-intercept
C	5-m x 5-m quadrats 4-m x 4-m quadrats Point-centered quarter distance method 1-m belt transects (parallel to zones) for density 1-m belt transects (perpendicular to zones) for density Modified line-intercept Qualitative cover estimates within 4-m x 4-m quadrats 1-m belt transects (parallel to zones) for cover estimates 1-m belt transects (perpendicular to zones) for cover estimates

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Source: ESE, 1981.

problems were similar in extent to those encountered for trees in the other sites.

156. Shrub line-intercept transects were identical to those used for trees. The sampling method differed, however, in that each 1-m interval was divided into twenty 5-cm segments. Presence of each shrub species within the 5-cm segments was established by moving the vertical sighting rod along the tape. Wherever the rod physically intercepted the vegetation or the vertical projection of shrub cover greater than 3 m in height, the species was recorded as being present. Frequency of occurrence of each species in the 20 segments of each meter was recorded as an approximation of the cover value for that 1-m interval.

157. Qualitative canopy cover estimates for shrubs were made in the 4-m by 4-m quadrats in the same manner as for trees.

158. Belt transects 1 m wide were established at Site C, both parallel to the vegetation zones and perpendicular to the zones. Two transects were established in each sampling zone parallel to the zone boundaries. Each transect ran through the midpoint of one of the two bands formed by the grid units. A total of 60 m<sup>2</sup> in each zone was sampled. Six perpendicular transects were established running from the lower (wetland) edge of the site to the upper edge. Two transects were randomly placed in each of the three grid units, so that a total of 60 m<sup>2</sup> per zone also was sampled by this method. Both placements thus sampled 10 percent of the stand area.

159. Each belt transect was divided into 1-m lengths, forming units of 1 m<sup>2</sup>. All stems were counted within each unit and a qualitative estimate of shrub cover within each unit was made.

#### Quantitative sampling methods for herbs

160. Table 5 lists the methods employed for sampling the herbaceous strata. Herbs were defined as any plants with stem

Table 5  
Listing of Herb-Sampling Methods Used  
at Each Phase I Sampling Site

<u>Site</u>	<u>Methods</u>
A	0.25-m <sup>2</sup> , 0.50-m <sup>2</sup> , and 1.00-m <sup>2</sup> square quadrats 0.25-m <sup>2</sup> , 0.50-m <sup>2</sup> , and 1.00-m <sup>2</sup> rectangular quadrats 0.25-m <sup>2</sup> , 0.50-m <sup>2</sup> , and 1.00-m <sup>2</sup> circular quadrats Qualitative cover estimates in quadrats 0.25-m-wide belt transects Modified line-intercept
B	0.25-m <sup>2</sup> and 0.50-m <sup>2</sup> square quadrats 0.25-m <sup>2</sup> and 0.50-m <sup>2</sup> rectangular quadrats Qualitative cover estimates in quadrats 0.25-m-wide belt transects Modified line-intercept Point-intercept method
C	0.25-m <sup>2</sup> and 0.50-m <sup>2</sup> square quadrats 0.25-m <sup>2</sup> and 0.50-m <sup>2</sup> rectangular quadrats 0.25-m <sup>2</sup> and 0.50-m <sup>2</sup> circular quadrats Qualitative cover estimates in quadrats 0.25-m-wide belt transects Modified line-intercept Point-intercept method

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Source: ESE, 1981.

diameters of less than 2 cm (0.78 in) at heights of 10 cm, or any plant with a maximum height of less than 61 cm (24 in).

161. When sampling for density of herbs, several different definitions of what constitutes a single individual had to be made, depending on the growth form of each species.

Single-stemmed herbs and bunch grasses were counted as single individuals. Where several stems all arose from the same point at the base of the plant, an individual was counted as one plant. In species such as partridgeberry or pennywort (Hydrocotyle spp.), where several flowering or leaf-bearing stems may arise at separate points from rhizomes or repent stems, each separate stem location was treated as a separate plant. For graminoid species such as cordgrasses (Spartina spp.) and spike rushes (Eleocharis spp.), each single culm was counted as an individual. Floating species such as duckweed could not be counted readily.

162. Square and rectangular quadrats consisted of wood frames with one removable side held by pegs so that quadrats could be centered around obstructions. All rectangular quadrats had end-to-side ratios of 1:2. Circular quadrats were constructed of 0.33-cm (1/8-in) diameter aluminum clothesline wire, with the ends joined by collars of tygon tubing.

163. A nested quadrat approach was used for obtaining the various sized quadrats. Quadrats were centered as closely as possible around the designated sampling point.

164. At Sites A and B regular, random, and stratified random placements were utilized. A total of ten 0.25-m<sup>2</sup> square and ten rectangular quadrats were located in each 10-m zone for each of the placements. Five quadrats of each of the other sizes or shapes were used.

165. At Site C, quadrats were laid out only in a stratified random arrangement, utilizing 20 0.25-m<sup>2</sup> square and rectangular quadrats per zone and 10 of each of the other size and shapes.

166. Qualitative cover measurements were made in the same way as for trees and shrubs. All estimates were made within 0.50-m<sup>2</sup> square quadrats.

167. The line-intercept transects at each site also were used to establish 0.25-m belt transects running perpendicular through the zones. A wood frame was used to mark out 0.25-m by 0.50-m quadrats along this line. A total of 15 to 25 m<sup>2</sup> was sampled in each zone by this method.

168. Line-intercept sampling methods were identical for both shrubs and herbs. In Site C, the line-intercept method was used for 1-m lengths along the sides of the square quadrats and along the point-intercept frames.

169. The point-intercept or point-contact method (Levy and Madden, 1933; Goodall, 1952, 1953a) was used in conjunction with quadrat sampling in Sites B and C in a stratified random pattern, with 30 to 40 sampling points per zone. The point-intercept frame utilized contained ten holes spaced at 10-cm (3.9-in) intervals (Mueller-Dombois and Ellenberg, 1974). Pin diameter was approximately 3.2 millimeters (mm) (0.125 in). At each sampling point, the frame was positioned parallel to the zones and the pin lowered successively through each of the ten holes. The species or item first contacted by the pin (all-contacts variation) in each hole was recorded. Frequency based on the ten pin contacts at each point was used as an approximation of cover. One person could perform all point-intercept sampling.

#### Data analysis--selection of analysis parameters

170. Available resources allowed comparison of density and cover only, although the data collected were sufficient for determination of such parameters as density, cover, frequency, basal area, and importance value. Frequency was not selected because this variable is not independent of sample size and number, making it inadequately suited for simple statistical

treatment. Although basal area and importance values are expected to follow a pattern similar to that of density, they are presumed to be more variable because the data consist of two measured variables (diameter measures as well as stem counts). Since these parameters require a greater analysis effort and are not applicable to all strata, they were not considered further in the efficiency evaluations.

171. In order to determine the best sampling methods, several important attributes should be evaluated. The following criteria were selected for use in determining the best method:

- a. Degree of variability and replicability of data.
- b. Field efficiency.
- c. Accuracy of the resulting zone or site characterization.

#### Variability evaluation

172. For this study, the measure of variability used was the SEM. Prior to initiation of this study, the Project Officer directed that a 15-percent SEM be used as a satisfactory level of performance, meaning that the SEM must be no more than 15 percent of the value of the mean (i.e.,  $SEM \leq 0.15X$ ). Lindsey *et al.* (1958) referred to such a specified level as a "constant adequacy level" (CAL).

173. A hierachial approach was used to evaluate methods further. Because of the directive concerning the CAL, the percent SEM values were used as the primary criteria of evaluation.

174. The SEM is an estimate of the precision of the mean value of a variable (Greig-Smith, 1964). In essence, it is a measure of the degree of variability of the sample mean of successive measurements around a true population mean. With a 15-percent SEM, it is probable that 67 percent of the means calculated will be within 15 percent of the true mean value, and that the remaining 33 percent of the calculated means would be

more than 15 percent away from the true value (Lindsey et al., 1958). In most of our analyses, a CAL of 15 percent was used. However, in some of the comparisons for the tree stratum, a 10-percent CAL was used for further comparisons.

175. Since the sites were centered on areas of environmental gradients, a nonrandom, non-Poisson distribution was assumed. A finite population for all species was also assumed since some populations were censused within entire study sites. The SEM used for nonrandom finite population was:

(1)

$$SEM = \sqrt{s^2/n}$$

with  $n-1$  degrees of freedom

where:  $s^2 = \text{the variance of the mean} = \frac{\sum x^2 - (\frac{\sum x}{n})^2}{(n-1)}$

$n = \text{the number of sample units within the sample}$

$x = \text{individual data points of sample units.}$

#### Field efficiency evaluation

176. A hierarchical evaluation process was used to evaluate field efficiency. First, a method was required to produce results sufficient to meet the CAL. The most efficient method was defined as that which takes the shortest field time to produce this level. In order to make this evaluation, two separate steps were necessary.

177. The first step in determining field efficiency was calculating the running mean, variance, and SEM of successively larger sample numbers. These values generally were calculated for quadrat methods with sample sizes beginning at  $n = 3$  and increasing in the following progression:  $n = (3, 5, 8, 10, 12,$

15, 18, 20, ...) until all sample quadrats were counted. At each interval, the percent SEM (SEM/X) was computed.

178. The second step involved computing the field time required for the method at the level of effort (number of sampling units) required for the CAL.

179. In order to develop measures of elapsed field time, two components of mean field time had to be defined. These components were the fixed time per sample ( $T_f$ ) and the variable time ( $T_v$ ) per sample. The fixed time per sample is defined as the amount of time actually spent at or within a sample unit while counting or sampling and recording the population parameters, as well as mean time spent directly moving from that unit to the next while sampling. Mean fixed time per sample is defined as:

$$T_f = \frac{\sum T_n}{n} \quad (2)$$

where:  $T_n$  = the total sampling time for a single sample, and

$n$  = the number of samples.

180. Variable time per sample consists of those activities which must be undertaken regardless of the number of sample units or points sampled in one series. Variable time would include such items as laying out base lines from which one or more perpendicular line transects would be begun. It would also include setting out a grid within which smaller quadrats would be located, or a base line along which one or more sample points would be located.

Variable time per sample is defined as:

$$T_v = \frac{T_i}{n} \quad (3)$$

where:  $T_i$  = the time required for the initial time expended before any sampling can begin, and

$n$  = the number of samples.

181. The fixed time per sample and the variable field time per sample can then be combined in various fashions to develop two separate parameters of elapsed field time. The field time parameter selected consisted of the cumulative time necessary to sample n units. Cumulative time, the time required for initial setup independent of sample size ( $T_i$ ), plus total sampling time is calculated as follows:

$$T_{cn} = T_i + \sum_{i=1}^{i=n} T_f \quad (4)$$

182. Field efficiency was compared first in terms of the relation between cumulative time ( $T_{cn}$ ) for increasing sample sizes and the resulting percent SEM for each size. The most efficient methods were those with the lowest cumulative time requirements necessary to reach 15 percent or 10 percent CAL of the percent SEM.

183. A second method of evaluation was chosen to increase the degree of resolution of the efficiency evaluations. This method was loosely based on Wiegert's (1962) concept of relative variance-relative cost ratios. For this report, a concept of relative efficiency per unit effort was developed which utilized the total or cumulative time necessary to reach a particular percent SEM value. This cumulative relative efficiency value is expressed as:

$$E_c = T_{cn} \times \% \text{ SEM} \quad (5)$$

184. The resulting  $E_c$  value provides an index value of sample efficiency combining sampling time and degree of sample error. It can be seen from the above equations that a reduction in the value of  $T_{cn}$  or percent SEM causes a reduction in the  $E_c$  value. Consequently, a low  $E_c$  value represents a high

degree of efficiency per unit sample time (see Table 9) or, in other words, a high level of return per unit effort. Figure 7 (see Part III) shows a typical relationship of percent SEM to cumulative sample time. Such graphical representations of  $E_C$  often provide better resolution for comparing efficiencies than the basic percent SEM curves.

#### Descriptive accuracy evaluation

185. Due to possible inherent sampling bias of certain methods or varying potentials for human bias, it is fully possible that certain methods could have high levels of efficiency and low variability and yet not yield results which are representative of the true population of an area. For potential delineation of wetlands and transition zone boundaries, such deficiencies would be damaging indeed.

186. Four separate attributes of the quantitative data were used in evaluating and ranking the accuracy of methods. The most important of these, in terms of the goals of transition zone analysis, is the similarity of sample species composition to the true species composition of the site. The quantitative similarity index selected for this study is the Bray and Curtis (1957) adaptation of Sorenson's Index of Similarity ( $IS_{BC}$ ), which reads:

$$IS_{BC} = \left( \frac{\sum M_w}{M_w + M_s} \right) \times 100 \quad (6)$$

where:  $M_w$  = the smaller quantitative value of a species common to the stands or data sets.

187. The Bray-Curtis modification is used to adopt indexing to relative values (i.e., percents) where the sum of all values is 100 (percent) (Mueller-Dombois and Ellenberg, 1974). In this method, the relative importance values for each species in two data sets are compared and the lower value is recorded. By summing the lower value of all species, an index value is

obtained. If the relative values of all species are identical, a maximum similarity value of 100 percent is obtained.

188. Whenever possible, we have compared data sets for each method to the data set from a complete census of the sampling area. Where this was not possible, as in cover determinations or herbaceous plots,  $IS_{BC}$  values for each pair of methods were calculated, and the mean value of all such comparisons for each method calculated. In general, higher mean values indicate more accurate methods, as these methods would yield results most representative of the results of all methods combined. However, care had to be used in such comparisons, when some methods varied only slightly in procedure, because the results would also tend to be similar. The data produced from these methods would skew results in favor of any group of procedurally similar methods and would bias the comparisons.

189. Methods were ranked on two other attributes relating to species similarity and the true community composition. These attributes were the number of species of the true community which were missed or omitted by a method (nonresponse) and the number of species recorded by a method which actually did not occur within the study area boundaries. Such qualitative data were combined to compute Sorenson's similarity index ( $IS_s$ ):

$$IS_s = \frac{2C}{A + B} \times 100 \quad (7)$$

where: C = number of species common to both sites,  
A = number of species found only in Site A, and  
B = number of species found only in Site B.

Although it was felt that actual omissions or additions were important criteria for the Phase I evaluations, the qualitative index was employed for most Phase II evaluations.

190. The final accuracy evaluation was based, where possible, on the quantitative data for total density per unit area. The degree of deviation of the sample mean from the true mean was used as a criterion.

191. All accuracy determinations were based on the minimum sample size determined to be necessary to meet the percent SEM constant adequacy levels. Where sampling intensity was not sufficient to reach these levels, the most intensive sampling level was used for accuracy determinations and CAL was estimated. Estimations of the number of sample units (*n*) required to reach the CAL were based on observation of the percent SEM curves and on the following formula (Lindsey, 1955):

$$n = \frac{s^2 - 100^2}{\bar{x}^2 \cdot r^2} \quad (8)$$

where:  $s^2$  = observed variance,  
 $\bar{x}$  = observed mean of samples, and  
 $r$  = required CAL, an integer.

192. Evaluations of methods were based on total community density or cover. Greater sample times were involved to reach adequate levels for all species. Problems with nonrandom distributions also may be greater for single species measures.

193. However, single species comparisons were run for some data which were felt to be the most reliable. In these comparisons, the first and second dominants, a median species, and a minor species were compared to total community efficiencies.

### PART III: PHASE I STUDY--RESULTS AND DISCUSSION

#### Vegetative Structure and Composition of Study Sites

194. The three Phase I sites differed in several parameters of overstory structure (Table 6). Density of trees within zones ranged from no trees in the Site C marsh to 1,830 trees per hectare (ha) in the cypress-tupelo-gum swamp. All zones in Site B were characterized by greater density and basal area values than in the other sites, as well as by greater numbers of species found. However, the species number in proportion to the number of stems counted is no higher than in the other sites, indicating that species number may be a function of stem number rather than site characteristics.

195. Sites A and C were the two sites with marsh grading into oak-pine uplands. These sites were similar in species number, density, and pattern. For both sites, density and basal area per ha increased from wetland to upland.

196. In Site B, this pattern was reversed, with density and basal area increasing toward the wetland end of the gradient. The greatest number of species found was in the transition zone of Site B, which represents an ecotone between two separate forest types.

197. A total of 42 species was found in the overstory strata of the three sites (Appendix B, Table B1). Thirty species were found in Site B, 18 species in Site A, and 12 species in Site C. Of these, 20 species occurred only in Site B, 5 only in Site A, and 2 only in Site C.

198. The three Phase I sites also differed substantially in patterns of shrub occurrence (Table 7). All of the sites showed different density-cover trends along the wetland-upland gradient. Wide variations in density, cover, and species number occurred among sites and among zones, showing that the sampling program did

Table 6  
Structural Characteristics of the Overstory Stratum  
at Three Phase I Sampling Sites

Site	Parameter*	Zone			
		Second Upland Zone	Upland Zone	Transition Zone	Wetland Zone
A	Density**	715.00	570.00	355.00	5.00
	Basal Area†	16.35	15.26	11.06	0.01
	Mean Stem Diameter††	17.07	18.46	19.93	5.04
	Species Number	13	12	8	1
C	Density	—	583.35	366.30	0.0
	Basal Area	—	26.62	10.55	0.0
	Mean Stem Diameter	—	24.11	19.15	—
	Species Number	—	7	10	0
B	Density	—	1095.00	1150.00	1830.00
	Basal Area	—	24.08	43.06	68.54
	Mean Stem Diameter	—	16.73	21.84	21.84
	Species Number	—	16	24	10

\* All values based on census.

\*\* Number stems per ha.

† m<sup>2</sup>/ha.

†† cm.

Source: ESE, 1981.

**Table 7**  
**Structural Characteristics of the Shrub Stratum**  
**at Three Phase I Sampling Sites**

Site	Parameter*	Zone			
		Second Upland Zone	Upland Zone	Transition Zone	Wetland Zone
A	Density**	8343.75	7520.00	3687.50	—
	Mean Cover	85.59	63.74	43.10	—
	Species Number	19	21	15	—
C	Density	—	1916.67	2988.33	3166.77
	Mean Cover	—	26.20	65.80	51.80
	Species Number	—	24	18	7
B	Density	—	6343.75	6979.17	6343.75
	Mean Cover	—	37.70	36.50	31.20
	Species Number	—	25	35	16

\* Density values based on census (Site C) or 4-m x 4-m quadrat data (Sites A, C); cover based on line-intercept data.

\*\* Number individuals per ha.

† Percentage.

Source: ESE, 1981.

indeed cover a wide diversity of shrub conditions. Site B was characterized by a high density of relatively small shrubs with little variation in pattern among zones. Sites A and C had similar transition zones with moderate numbers of fairly large shrubs. Sites A and C, however, varied largely in shrub densities in wetland and upland zones, although shrubs, when present, were similarly moderate in mean shrub size.

199. Shrub species composition did not necessarily follow the same patterns as density and cover values. Highest species numbers and greatest differences in species composition among zones (Appendix B, Table B2) occurred in Site B, where the least density-cover variations occurred. In Sites A and C, Ilex vomitoria and Brunnichia cirrhosa tended to dominate the upland ends of the gradient, while Baccharis halimifolia, Sabal minor, and Iva frutescens dominated in the wetter areas.

200. No census was made of herbaceous plants in any site. Wide variations usually occurred among density and cover results from various methods. Consequently, Table 8 shows the ranges of density and cover values for the herb strata as obtained from different methods. Again, the data show that a wide range of conditions was encountered within the three sites. Recorded cover values ranged from less than 1 percent in the heavily shrub-dominated upland of Site A, to values of well over 100 percent (cumulative for all species) in the graminoid brackish marsh of Site A.

201. The apparently anomalous incident of high cover and low density in the cypress-tupelo-gum wetland (Site B) is explained by the fact that the floating nonrooted duckweed (Lemna minor) was included in the cover estimates but not in the density measurements. When the duckweed is omitted, the resultant cover values in this zone drop to less than 1 percent.

Table 8  
Structural Characteristics of the Herbaceous Stratum  
at Three Phase I Sampling Sites

Site	Parameter*	Zone			
		Second Upland Zone	Upland Zone	Transition Zone	Wetland Zone
A	Density**	6.80-15.60	5.52-12.56	80.50-322.64	348.33-874.78
	Cover†	0.96-16.08	1.13-18.75	45.65-90.25	87.76-97.08
	Species Number	19	16	28	3
C	Density	—	51.36-58.00	47.04-58.00	340.12-409.76
	Cover	—	45.16-96.25	40.11-88.95	70.66-193.33
	Species Number	—	16	16	13
B	Density	—	18.48-219.60	24.40-100.00	0.80-14.00
	Cover	—	1.24-4.63	1.00-1.04	80.01-100.28
	Species Number	—	21	19	10

\* Values shown are ranges from all methods.

\*\* Number per m<sup>2</sup>.

† Percentage.

Source: ESE, 1981.

## Overstory Sampling Methods

### Variability and efficiency

202. Figures 7 and 8 show the relationships between cumulative field sampling time and percent SEM for three zones each in Sites A and B. In each case, the values shown are based on total density of all species, and in effect treat the community as a single random population.

203. In Figures 7 and 8, each line represents the decrease in percent SEM with increase in sample effort or time. The field sampling time required to reach a specified CAL can be estimated by determining the point at which a curve crosses a horizontal line drawn from the percent SEM value chosen as the CAL.

204. Consistent throughout all zones is a pattern in which the cover estimation methods and distance (plotless) methods show the most rapid decrease and therefore highest replicability and efficiency at the lower cumulative sample times. Efficiencies of circular quadrat methods generally are intermediate between these and the efficiencies of square and rectangular quadrat shapes.

205. The shorter sample times required for the cover and distance methods in particular are a result of the fact that initial setup time ( $T_i$ ) was much less than that required for those quadrats with measured linear dimensions. However, with the sampling intensity used in this study, CAL was rarely reached during field sampling by any of the cover or plotless methods. For these methods, the sample size and resultant field time needed to reach CAL was calculated using Equation (8) found on Page 85. On the basis of the calculated sampling time required to reach CAL, a considerable amount of variation appears in the time requirements of the plotless methods.

206. From these data, it does not appear possible to predict whether the point-quarter or the wandering quarter method has greater overall efficiency under all possible conditions.

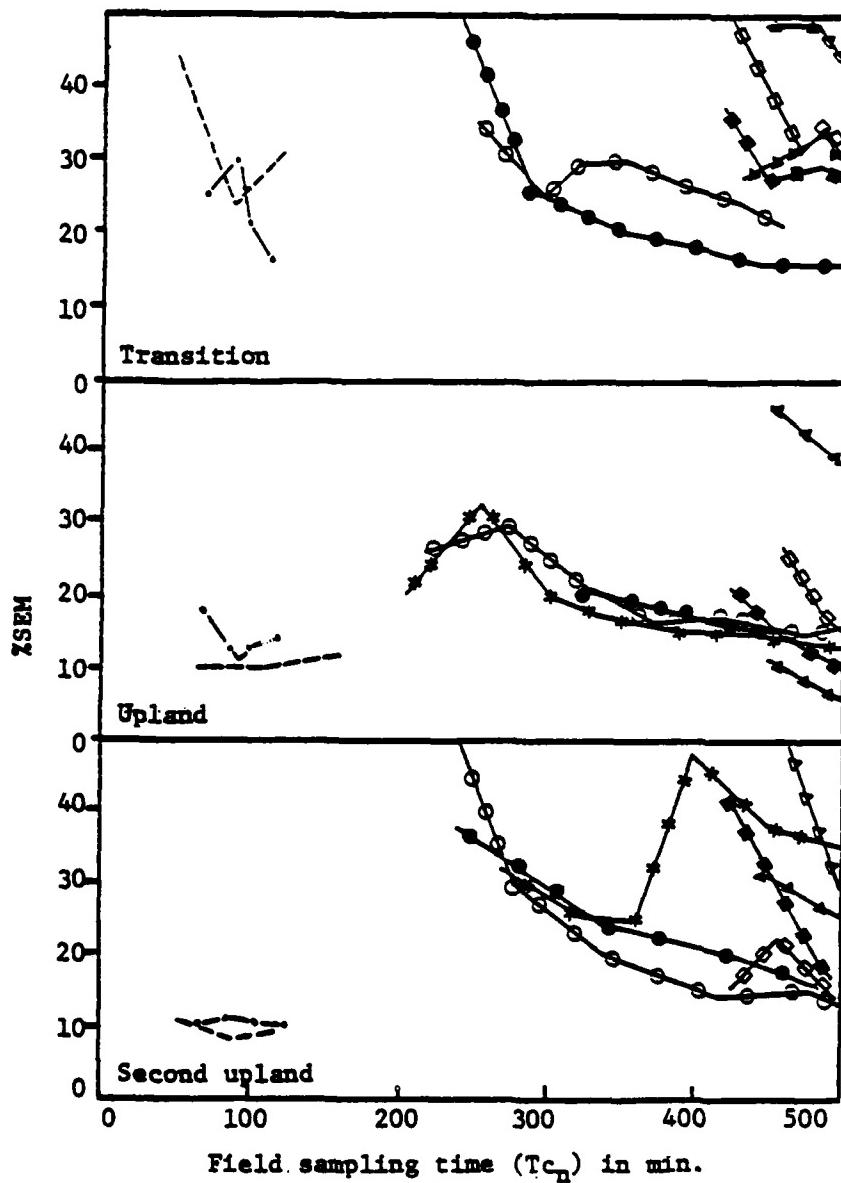


Figure 7. The  $ZSEM$ -sampling time relationships ( $E_c$ ) for nine overstory sampling methods in three zones of Site A. Methods shown are:

- |                              |     |                                    |                |     |
|------------------------------|-----|------------------------------------|----------------|-----|
| 100- $m^2$ circular quadrats | (○) | 10-m x 20-m parallel quadrats      | (△)            |     |
| 200- $m^2$ circular quadrats | (●) | 10-m x 20-m perpendicular quadrats | (▲)            |     |
| 10-m x 10-m quadrats         | (□) | Point-centered quarter             | (*)            |     |
| 5-m x 20-m quadrats          | (■) | Cover estimation                   | (----)         |     |
|                              |     |                                    | Line-intercept | (—) |

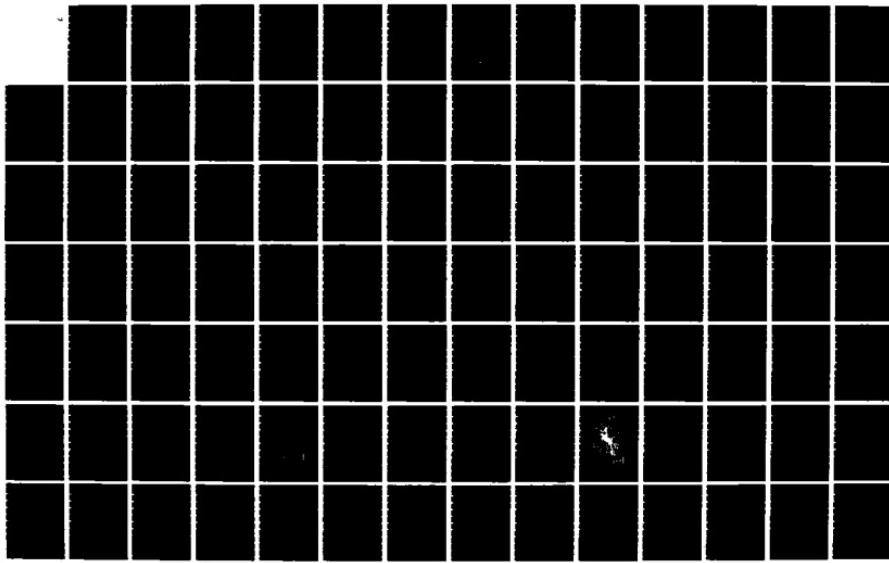
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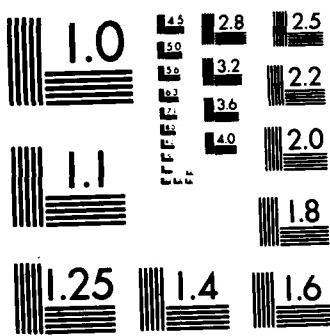
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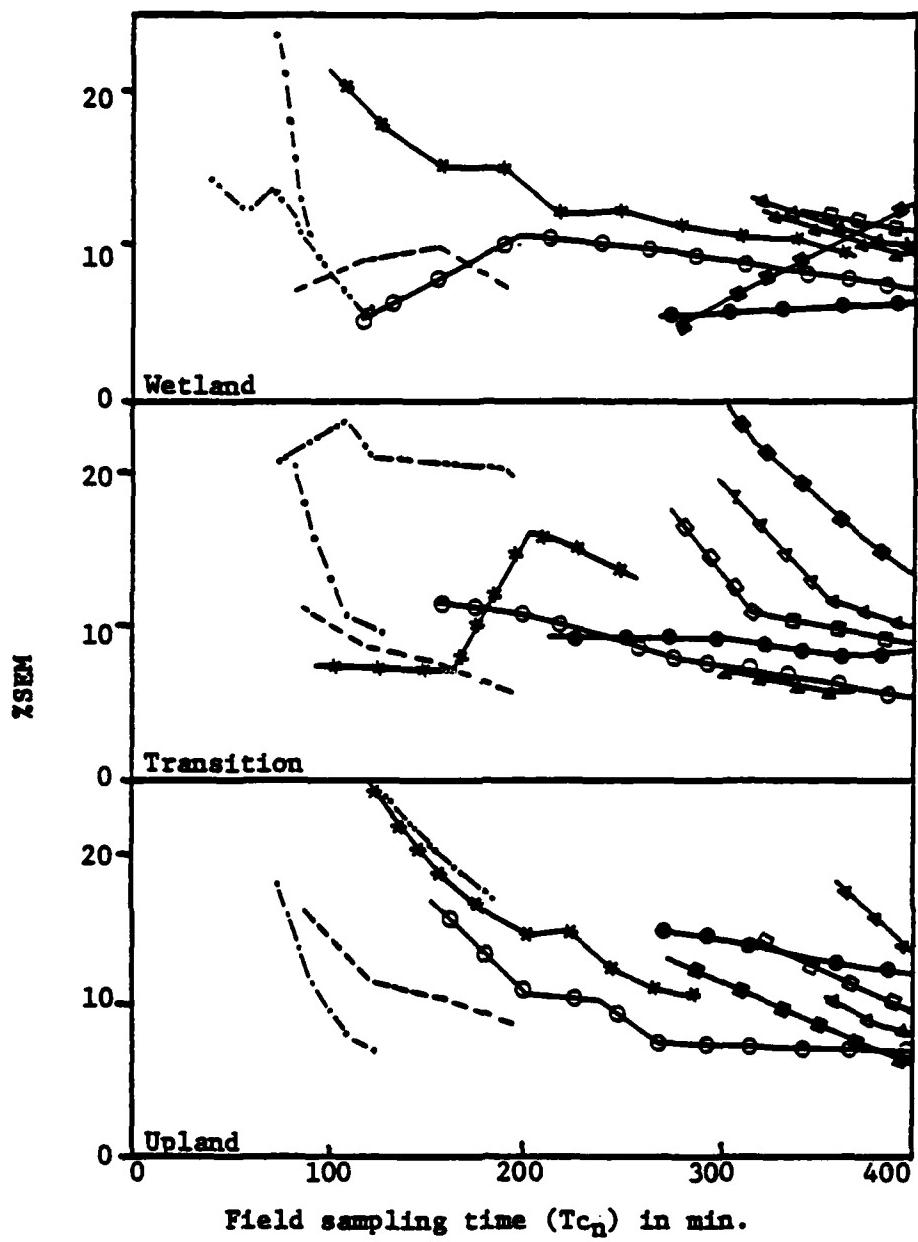


Figure 8. The %SEM-sampling time relationships ( $E_c$ ) for 10 overstory sampling methods in three zones of Site B. Methods shown are:

- |  |                               |
|--|-------------------------------|
| 100-m <sup>2</sup> circular quadrats (○) | Point-centered quarter (*)    |
| 200-m <sup>2</sup> circular quadrats (●) | Wandering quarter (- - - - -) |
| 10-m x 10-m quadrats (□)                 | Cover estimation (- - - - -)  |
| 5-m x 20-m quadrats (■)                  | Line-intercept (—)            |
| 10-m x 20-m parallel quadrats (△)        |                               |
| 10-m x 20-m perpendicular quadrats (▲)   |                               |

207. Similar patterns are apparent in the graphs shown for cumulative relative efficiency ( $E_c$ ). The results of the percent SEM and  $E_c$  analyses showed no consistent pattern, indicating a difference in efficiency of either shape or size among square and rectangular quadrats.

208. Table 9 summarizes the measured or predicted sampling efforts needed to reach a specified CAL for each zone or site.

209. In order to compare the  $E_c$  of each method on a common basis, the  $E_c$  based on a standardized cumulative sampling time was compared. Also in Table 9, the calculated  $E_c$  is shown for each method at the sampling intensity which has a field time closest to 300 minutes.

#### Accuracy

210. Tables 10 and 11 show relative dominance (as measured by relative density or relative cover, as appropriate) for each overstory sampling method, as well as true values from full census data for each site. Relative dominance values are shown for selected species in each zone, including the four most prevalent species, the median species, and one of the least prevalent species. These species were selected as representative of the types and magnitudes of errors for each method in reporting relative values for species. Values shown are those obtained from each method at the minimum effort necessary to reach a CAL of 15-percent SEM for Site A and 10-percent SEM for Site B, or the maximum sample size used.

211. In general, the ability to rank the most prevalent species accurately by dominance is linked to the time expended in sampling. The square and rectangular quadrats which required long sample times and the sampling of a large portion of each site gave consistently accurate results. Of the other methods, the 100-m<sup>2</sup> circular quadrats had the highest percentage of accurate rankings of the four most prevalent species.

**Table 9**  
**Measured or Predicted<sup>a</sup> Sampling Intensities Needed to Reach 1% SEM or 10% SEM  
 Constant Adequacy Levels (CAL) for Overstory Sampling Methods**

Site and Zone	Sampling Requirements to Reach CAL	Sampling Method									
		Percent					% Line Intercept				
		10-m <sup>b</sup>	5-m <sup>b</sup>	Parallel	10-m <sup>b</sup> x 10-m <sup>b</sup>	100-m <sup>b</sup>	200-m <sup>b</sup>	Point-Centered	Circular	Quarter	% Cover Estimate
Site A—1% SEM											
Upland	# Samples	10	10	10	10	12	11	16	—	2	5
	# Trees	81	74	143	143	93	157	64	—	—	—
	Area sampled	1000	1000	2000	2000	1200	2200	—	—	200	25
	Time (min)	511	510	648	648	418	515	1448	—	73	61
	E <sub>c</sub> ††	63.5	173.9	249.5	140.3	66.5	87.3	82.1	—	12.2	11.3
Upland	# Samples	10	15	10	2	22 <sup>b</sup>	8	16	—	8	5
	# Trees	66	81	114	119	125	84	64	—	—	—
	Area sampled	1000	1500	2000	400	2200	1600	—	—	800	25
	Time	505	569	591	452	618	420	417	—	85	80
	E <sub>c</sub>	50.1	88.3	212.8	50.4	43.8	67.8	58.3	—	14.4	19.4
Transition	# Samples	395	395	305	305	395	28	12	—	285	52
	# Trees	138	138	213	213	138	169	48	—	—	—
	Area sampled	3000	3000	6000	6000	3000	5600	—	—	2800	260
	Time	1018	1018	1515	1515	920	782	378	—	129	436
	E <sub>c</sub>	113.5	154.3	221.4	125.8	72.2	75.6	56.7	—	19.4	36.3

(Continued)

\* When actual sampling did not give results reaching the CAL, the formula  $n = \frac{s^2}{X^2} \cdot \frac{100^2}{Z^2}$  (q) was used with the most intensive sample size to predict the number of samples (n) needed.

† Sample size based on number of quadrats for quadrant methods; number of points for point-quarter, groups of 5 trees for wandering quarter, and number of 1-m units for line intercept methods.

<sup>b</sup> Areas in m<sup>2</sup> for all methods but line intercept, which is in m.

†† E<sub>c</sub> values shown are for sampling intensity with time requirements closest to 300 min.

(Sheet 1 of 3)

Table 9 (Continued)

Site and Zone	Sampling Requirements to Reach QL	# Samples	Sampling Method									
			Perpen-			Parallel			Point-			% Cover
			10-m x 10-m	5-m x 10-m	10-m x 20-m	10-m x 10-m	20-m x 20-m	Circular	Centered	Quadrat	Quarter	Estimate
<b>Site B-15% SEM</b>												
Upland	# Samples	5	3	4	6	8	5	12	14	5	5	8
	# Trees	56	41	86	133	95	85	48	70	—	—	—
Area sampled	500	300	800	1200	800	1000	—	—	500	40	40	40
Time	318	274	355	416	205	307	202	246	84	72	72	72
E <sub>c</sub> †	45.0	35.4	37.2	65.4	24.0	46.1	32.3	31.9	8.5	17.0	17.0	17.0
Transition	# Samples	5	10	4	2	5	5	18	18	10	10	8
	# Trees	66	101	86	47	46	68	72	90	—	—	—
Area sampled	500	1000	800	400	200	1000	—	—	1000	40	40	40
Time	320	395	356	302	156	216	241	331	98	72	72	72
E <sub>c</sub>	33.8	70.2	57.8	22.8	23.2	27.3	33.4	39.3	12.1	12.7	12.7	12.7
Wetland	# Samples	5	8	2	2	5	5	8	2	5	5	8
	# Trees	83	144	62	72	93	123	32	10	—	—	—
Area sampled	500	800	400	500	300	1000	—	—	500	40	40	40
Time	342	401	317	323	201	271	190	38	84	72	72	72
E <sub>c</sub>	41.9	29.3	43.5	36.0	28.7	34.0	31.6	9.3	7.9	14.4	14.4	14.4

(Continued)

\* When actual sampling did not give results reaching the QAL, the formula  $n = \frac{s^2 \cdot 100^2}{r^2 \cdot r^2}$  (q) was used with the most intensive sample size to predict the number of samples (n) needed. Estimated values are shown by superscript B.

\*\* Sample size based on number of quadrats for quadrat methods; number of points for point-quarter, groups of 5 trees for wandering, quarter, and number of 1-m units for line intercept methods.

† Area in  $m^2$  for all methods but line intercept, which is in  $m$ .

†† E<sub>c</sub> values shown are for sampling intensity with time requirements closest to 300 min.

(Sheet 2 of 3)

Table 9 (Concluded)

Site and Zone	Sampling Requirements to Reach CAL	Sampling Method											
		Perpendicular			Parallel			Circular			Point-Centering		
		10-m	5-m	10-m x 10-m	10-m	20-m	20-m x 20-m	Quadrat	Quadrat	Quadrat	Quarter	Quarter	% Cover Estimate
<b>Site B-10% SEM</b>													
Upland	# Samples	10	8	6	10	12	15	20	30	12	8	—	—
	# Trees	108	99	131	219	136	262	80	150	—	—	—	—
	Area sampled	1000	800	1200	2000	1200	3000	—	—	1200	40	—	—
	Time	392	362	389	531	271	460	290	499	102	72	—	—
Transition	# Samples	10	18	6	2	10	5	20	40	20	8	—	—
	# Trees	115	108	134	47	112	88	80	200	—	—	—	—
	Area sampled	1000	1800	1200	400	1000	1000	—	—	2000	40	—	—
	Time	395	519	412	303	241	216	260	705	125	72	—	—
Wetland	# Samples	10	15	10	4	8	5	20	10	8	8	—	—
	# Trees	181	264	366	140	163	123	80	90	—	—	—	—
	Area sampled	1000	1500	2000	800	1000	—	—	—	800	40	—	—
	Time	440	538	610	401	279	271	368	91	93	72	—	—

\* When actual sampling did not give results reaching the CAL, the formula  $n = \frac{\epsilon^2}{x^2} \cdot \frac{100^2}{r^2} \cdot q$  was used with the most intensive sample size to predict the number of samples (n) needed.

\*\* Sample size based on number of quadrats for quadrat methods; number of points for point-quarter, groups of 5 trees for wandering quarter, and number of 1-m units for line intercept methods.

† Area in  $m^2$  for all methods but line intercept, which is in  $m$ .

Source: ESE, 1981.

(Sheet 3 of 3)

Table 10  
Comparison of Relative Dominance\* of Representative Species of the Overstory Stratum  
at Site B, as Measured by Census and 10 Sampling Methods

Zone	Species	Sampling Method									
		Census		10-m <sup>2</sup>		5-m <sup>2</sup>		10-m <sup>2</sup> x 10-m <sup>2</sup>		20-m <sup>2</sup>	
		Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quarter	Quarter
<b>Upland</b>											
	<i>Quercus phellos</i>	27.85	17.59	24.24	33.59	27.85	26.38	22.80	23.80	22.00	1.41
	<i>Pinus strobus</i>	21.46	26.09	26.76	23.66	21.46	22.78	21.01	22.50	20.40	21.12
	<i>Symplocos tinctoria</i>	12.33	12.96	12.12	12.21	12.33	11.74	13.34	11.30	6.00	22.54
	<i>Vaccinium arboreum</i>	9.59	9.26	9.09	9.16	9.59	8.83	12.39	6.30	6.40	0.00
	<i>Liquidambar styraciflua</i>	2.28	1.70	1.03	1.05	2.28	3.68	2.67	1.30	4.00	0.00
	<i>Carya cordiformis</i>	0.46	0.93	0.00	0.00	0.46	0.73	0.76	0.00	0.80	0.00
<b>Transition</b>											
	<i>Pinus strobus</i>	18.70	20.87	22.16	18.67	20.83	17.86	26.14	16.30	14.00	23.33
	<i>Nyssa sylvatica</i> var. biflora	15.65	17.39	10.30	11.14	14.58	15.18	11.36	11.30	26.00	11.19
	<i>Quercus alba</i>	13.48	16.32	14.43	15.67	6.25	10.71	12.50	18.80	16.00	18.81
	<i>Quercus phellos</i>	10.43	11.30	9.27	6.71	16.67	16.07	1.14	6.30	2.00	9.19
	<i>Tilia americana</i>	0.87	0.87	1.03	0.75	0.00	0.89	1.14	0.00	0.33	0.00
	<i>Fagus grandifolia</i>	0.43	0.87	0.00	0.00	2.08	1.79	1.14	1.30	2.00	1.43
<b>Wetland</b>											
	<i>Nyssa aquatica</i>	36.70	26.73	31.05	36.70	27.86	26.34	29.03	35.00	44.00	41.83
	<i>Nyssa sylvatica</i> var. biflora	30.60	26.26	30.88	30.80	30.71	26.87	29.86	33.80	30.00	27.72
	<i>Premna caroliniana</i>	8.74	12.15	10.23	8.76	16.29	8.47	10.46	6.30	2.00	4.89
	<i>Ostrya virginiana</i>	7.92	11.05	9.85	7.92	12.86	13.76	16.13	7.50	10.00	9.80
	<i>Acer rubrum</i>	7.10	8.86	7.57	7.10	7.14	6.35	0.81	1.30	2.00	0.16
	<i>Quercus nigra</i>	1.09	1.66	1.32	1.09	14.29	1.99	2.42	0.00	0.00	0.55

\* Relative dominance expressed as percentage is based on relative density for density-based methods, and on relative cover for cover-based methods.

Source: ESE, 1981.

**Table 11**  
**Comparison of Relative Dominance\* of Representative Species of the Overstory**  
**Stratum at Site A, as Measured by 10 Sampling Methods and a Census**

Zone	Species	Sampling Method									
		Census		Quadrat		Quadrat		Point-Center		Warder-	
		10-m x 10-m	5-m x 20-m	10-m x 20-m	20-m	Quadrat	Quadrat	Quadrat	Quadrat	Quarter	Quarter
<b>Second Upland</b>											
	<i>Ilex vomitoria</i>	55.20	55.70	55.40	55.20	55.20	51.61	50.80	33.80	—	37.03
	<i>Quercus nigra</i>	16.10	16.50	17.6	16.1	16.13	16.9	20.0	—	7.41	48.3
	<i>Liquidambar</i>										
	<i>Styrax</i>	7.0	8.9	5.4	7.0	10.75	8.9	16.3	—	6.17	34.5
	<i>Quercus virginiana</i>	4.9	3.8	2.7	4.9	2.15	1.6	8.8	—	0	3.5
	<i>Taxodium cordifolium</i>	3.5	2.5	2.7	3.5	2.15	5.7	2.5	—	3.09	10.3
	<i>Acer rubrum</i>	0.7	0	1.4	0.7	0.7	0.8	0	—	0	3.5
<b>Upland</b>											
	<i>Ilex vomitoria</i>	27.19	15.15	33.33	27.19	21.05	27.19	21.42	3.13	—	9.84
	<i>Myrica cerifera</i>	18.42	16.67	14.81	18.42	15.79	18.42	19.06	25.01	—	19.68
	<i>Pinus taeda</i>	18.42	26.24	11.10	18.42	15.79	18.42	10.72	10.95	—	8.80
	<i>Quercus virginiana</i>	11.40	15.15	11.10	11.40	10.53	11.40	13.10	20.32	—	19.51
	<i>Quercus nigra</i>	5.20	4.55	6.18	5.26	10.53	5.26	14.28	6.26	—	11.81
	<i>Celtis laevigata</i>	0.88	1.52	1.26	0.88	0	0.88	0	6.26	—	0.20
<b>Transition</b>											
	<i>Pinus taeda</i>	19.72	19.72	19.72	19.72	21.13	31.20	25.00	—	33.92	78.58
	<i>Myrica cerifera</i>	19.72	19.72	19.72	19.72	18.31	16.00	17.50	—	18.63	0
	<i>Quercus virginiana</i>	15.49	15.49	15.49	15.49	15.49	12.68	14.40	25.00	—	27.42
	<i>Ilex vomitoria</i>	15.49	15.49	15.49	15.49	15.49	9.86	7.20	5.00	—	4.39
	<i>Fagus grandifolia</i>	9.86	9.86	9.86	9.86	9.86	12.68	6.40	7.50	—	0.88
	<i>Dipteronia texana</i>	4.32	4.23	4.23	4.23	4.23	4.23	2.40	7.50	—	3.69

\* Relative dominance expressed as percentage is based on relative density for density-based method, and on relative cover for cover-based methods.

Source: ESE, 1981.

212. Most methods showed similar accuracies in identifying and quantifying the less prevalent species. The line intercept and plotless methods tended to fail to identify several species. This trend is confirmed in Table 12 in which the number of species erroneously added to or omitted from those actually present is shown. An average of 9.5 species per zone was not identified by the line intercept method. Averages of 5.0 and 7.3 species were omitted with the point quarter and wandering quarter methods, respectively. All other methods omitted an average of less than three species, and were roughly comparable.

213. Those methods which tended to omit species actually present also tended to include species which did not occur in the censused area. The 200-m<sup>2</sup> circular quadrats also added species. In the case of the circular and the plotless methods, the distances required from the starting point of each sample tended to exceed the width of the sampled zone. The line-intercept method added those species overhanging, but not rooted, within a zone.

214. Table 12 also shows total densities as estimated for each method and the IS<sub>BC</sub> values compared to the census relative dominance values. Methods were judged to have suitable accuracy for overall density values if the estimated means were within +10 percent of the true value. All of the quadrat methods consistently fell within this range except for the 200-m<sup>2</sup> quadrats. Neither of the plotless methods was effective in estimating density.

215. Similar trends occurred for the similarity index values, with values for the quadrat methods higher than those for plotless or cover values. Manipulation of relative dominance values for artificial populations indicated that IS<sub>BC</sub> values of 85 percent or higher generally are sufficient to indicate that two samples have similar dominant species groupings.

**Table 12**  
**Indicators of Sampling Accuracy for 10 Overtory Sampling Methods. Similarity Value (IS<sub>pc</sub>)**  
**Based on Degree of Similarity to Census Values**

Site and Zone	Parameter	Census Value	Quadrat	Sampling Method							
				Parallel dicular	10-m x 5-m x	10-m x 20-m	10-m x 20-m	100-m <sup>2</sup> Circular	200-m <sup>2</sup> Circular	Point-Center Quadrat	Wander- ing Centered Quarter
<b>Site A</b>											
IS <sub>PC</sub>	-	95.40	91.90	100.00	100.00	91.66	93.00	71.90	-	66.90	30.80
# Species Added	-	0	0	0	0	0	0	3	-	0	0
# Species Omitted	-	2	1	0	0	1	1	4	-	4	8
Total Density/Cover	715	810	740	715	775	740	1262	-	81	116	
Upland		(333.0)	(347.0)	(327.9)	(327.9)	(351.5)	(332.9)	(1807.5)		(11.0)	(29.4)
IS <sub>PC</sub>	-	83.74	88.77	100.00	82.46	100.00	84.22	64.26	-	68.42	40.35
# Species Added	-	0	0	0	0	0	0	0	-	0	0
# Species Omitted	-	2	0	0	5	0	2	2	-	2	9
Total Density/Cover	570	660	540	570	475	570	563	543	-	64	88
Transition		(293.9)	(284.7)	(260.0)	(378.5)	(398.0)	(261.0)	(325.5)		(20.9)	(20.4)
IS <sub>PC</sub>	-	100.00	100.00	100.00	90.15	80.17	75.21	-	-	73.88	35.21
# Species Added	-	0	0	0	0	0	2	1	-	0	0
# Species Omitted	-	0	0	0	0	0	0	0	-	0	6
Total Density/Cover	355	355	355	355	355	355	354	-	-	28	48
		(333.9)	(326.3)	(290.2)	(332.4)	(232.7)	(207.3)			(22.8)	(50.6)

(Continued)

\* Density values expressed as stems per ha; cover values expressed as % cover. Mean (standard deviation).

Table 12 (Concluded)

Site and Zone	Parameter	Census	Sampling Method									
			Perpen-			Parallel			10-m x 20-m			Point-
			5-m x 10-m	5-m x 20-m	10-m x 20-m	10-m x 20-m	20-m x Circular	Quadrat	Quadrat	Quadrat	Quadrat	Wander-
<b>Site B</b>												
Upland	IS <sub>SC</sub>	-	87.58	86.12	89.59	100.00	92.29	91.20	76.06	78.27	78.90	64.45
	# Species Added	-	0	0	0	0	1	1	2	1	0	0
	# Species Omitted	-	2	3	2	0	2	0	8	8	4	12
	Total Density*/Cover	1095	1080	1238	1133	1095	1105	1800	1344	1621	104	148
		(340.0)	(282.6)	(241.0)	(292.0)	(346.7)	(429.0)	(670.2)	(694.6)	(694.6)	(34.5)	(68.5)
Transition	IS <sub>SC</sub>	-	85.64	90.29	91.33	76.29	86.50	75.41	75.41	66.78	81.63	66.94
	# Species Added	-	0	0	0	0	0	0	0	0	0	0
	# Species Omitted	-	8	2	4	10	3	5	12	11	1	16
	Total Density/Cover	1150	1210	1133	1150	1175	1130	1900	962	1090	105	205
		(341.9)	(428.2)	(255.0)	(125.0)	(346.6)	(400.0)	(552.9)	(695.2)	(695.2)	(45.6)	(63.8)
Wetland	IS <sub>SC</sub>	-	88.27	95.49	100.00	88.58	79.13	85.77	89.96	85.91	83.51	69.1
	# Species Added	-	0	0	0	0	0	2	0	0	0	1
	# Species Omitted	-	0	1	0	1	1	1	2	3	0	6
	Total Density/Cover	1830	1860	1627	1830	1750	1925	2520	2708	3008	107	145
		(512.3)	(620.0)	(497.6)	(379.8)	(509.3)	(292.6)	(261.7)	(971.1)	(28.1)	(29.6)	

\* Density values expressed as stems per ha; cover values expressed as % cover. Mean (standard deviation).

Source: ESE, 1991.

### Sampling variations

216. The wetland zone of Site B was selected to depict the further analyses of sampling variations because of the high density and the representative species number. The resultant patterns of this analysis are representative of those found for other zones and methods.

217. Figure 9 shows the relationships between percent SEM and cumulative field time for regular, random, and stratified random placement alternatives with 10-m by 10-m quadrats. These figures show values not only for the total combined populations, but also for several individual species. Curves are shown for the two most dominant species, Nyssa aquatica and Nyssa sylvatica var. biflora, a median species, Cephalanthus occidentalis, and one of the least prevalent species, Taxodium distichum.

### Shrub Sampling Methods

#### Variability and efficiency

218. Site C, the primary site for shrub analyses, was the only site in which the results from shrub sampling methods were compared to census data. No census was made at either Site A or Site B. Therefore, results from each method can be compared only against each other or with the mean results of all methods. One of the quadrat methods (4-m by 4-m), the point-centered quarter method, and the line-intercept method were evaluated at all three sites. Of the methods used at all three sites, the quadrat and line-intercept methods were sufficient to reach CAL in at least 67 percent of the instances in which they were evaluated, while the point-centered quarter method was never sufficient to reach CAL level at the sampling intensities which were used (Figures 10 through 12).

219. Tables 13 and 14 indicate the measured or predicted sampling intensities or efforts necessary to reach CAL for shrubs.

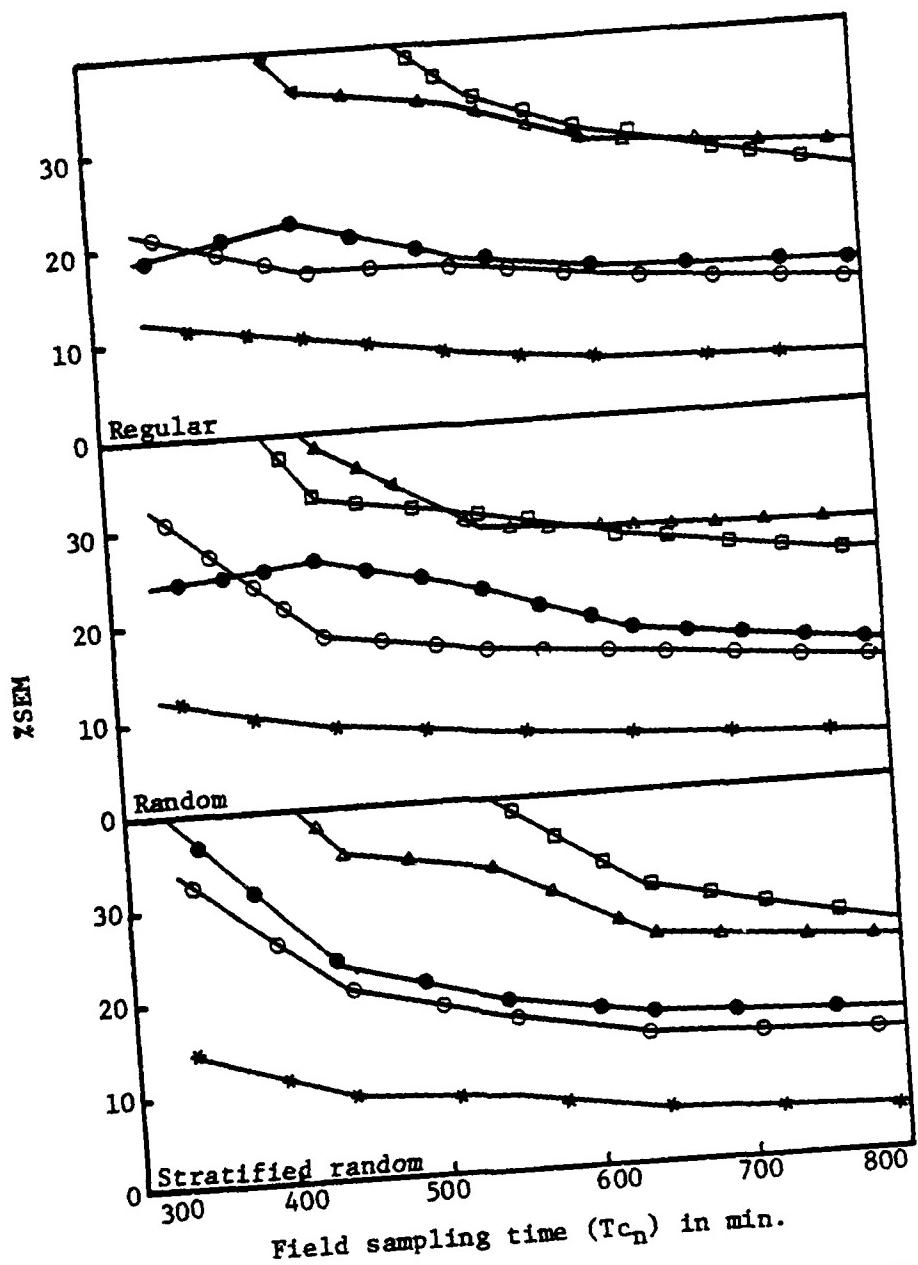


Figure 9. Effect of quadrat placement pattern on the %SEM-sampling time relationships for species of different densities. Data from 10-m x 10-m quadrats in wetland zone of Site B. Total combined populations (\*), *Nyssa aquatica* (O), *Nyssa sylvatica* var. *biflora* (●), *Cephalanthus occidentalis* (Δ), and *Taxodium distichum* (□)

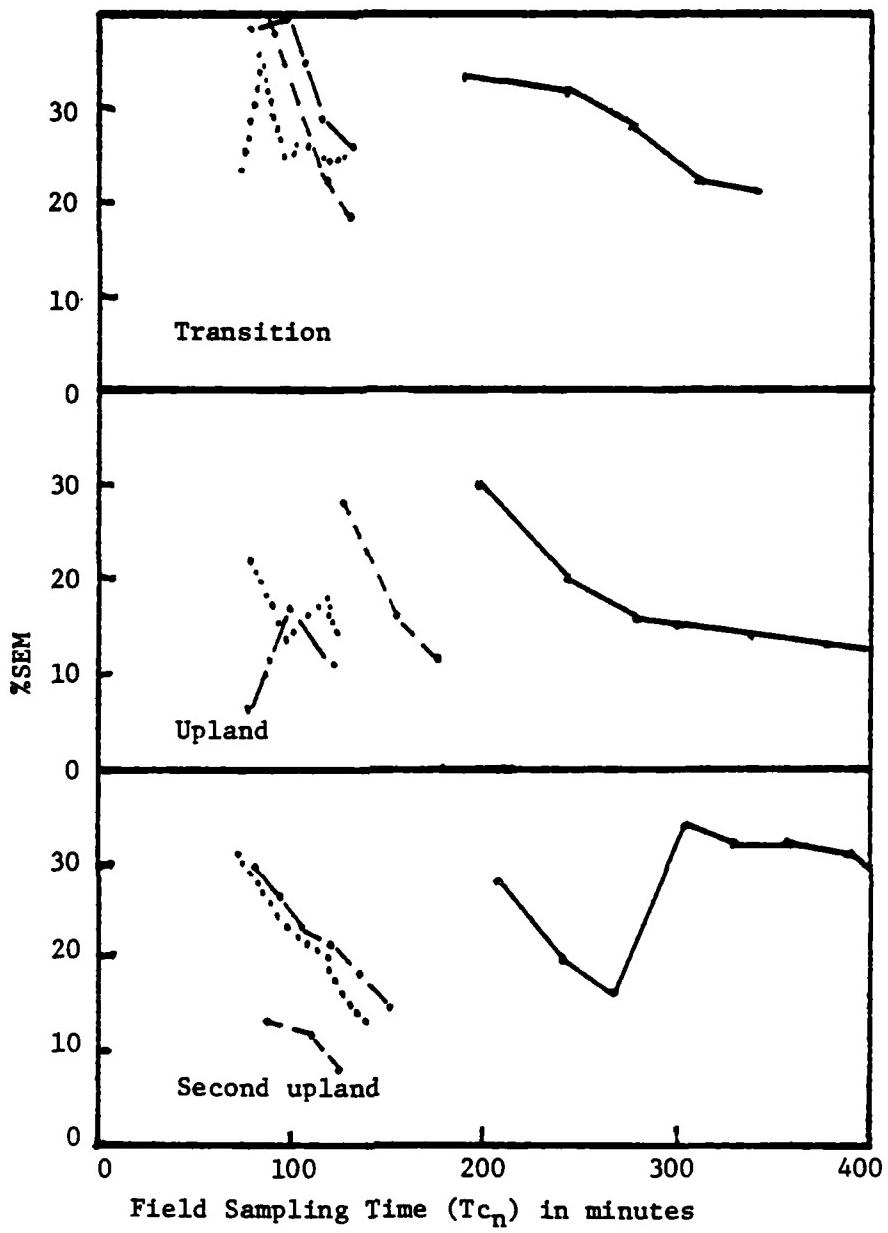


Figure 10. The %SEM-sampling time relationships for four shrub sampling methods in three zones of Site A. Methods shown are: 4-m x 4-m quadrats, regular placement (----); 4-m x 4-m quadrats, random placement (···); point-centered quarter (—); line-intercept (—).

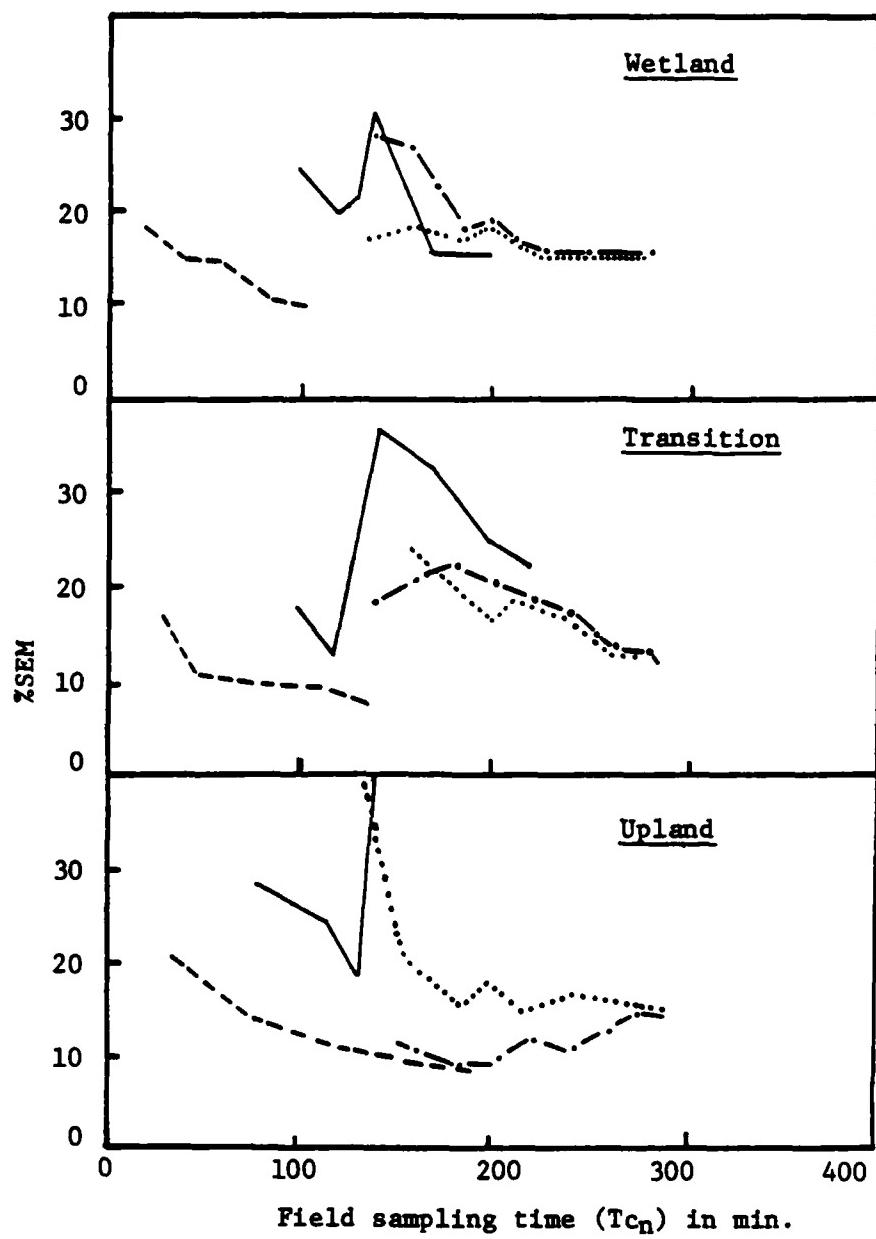


Figure 11. The %SEM-sampling time relationships for four shrub sampling methods in three zones of Site B. Methods shown are:  
 4-m x 4-m quadrats, regular placement (----)  
 4-m x 4-m quadrats, random placement (.....)  
 Point-centered quarter (—)  
 Line-intercept (---)

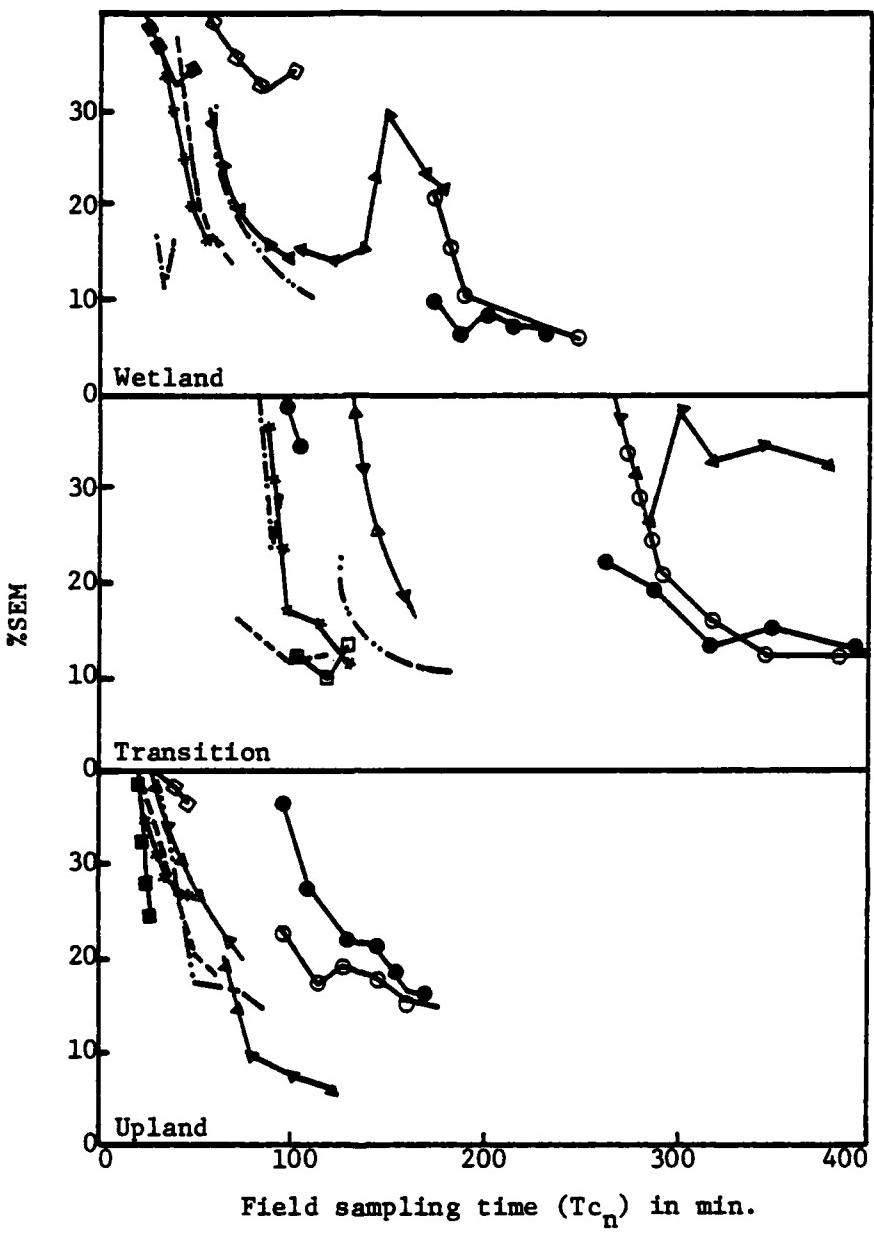


Figure 12. The %SEM-sampling time relationships for 10 shrub sampling methods in three zones of Site C. Methods shown are:

- 5-m x 5-m quadrats, regular placement (○)
- 5-m x 5-m quadrats, random placement (●)
- 4-m x 4-m quadrats, regular placement (□)
- Parallel belt transects (■)
- Perpendicular belt transects (△)
- Point-centered quarter (▲)
- Line-intercept (---)
- Parallel belt transect--cover (\*)
- Perpendicular belt transect--cover (---)
- Cover estimation (—·—)

**Table 13**  
**Measured or Predicted Sampling Intensities Needed to Reach 15% SEI Constant Adequacy Levels (CAL) for**  
**Shrub Sampling Methods at Site C**

Sampling Requirement to Reach CAL.	Zone	Sampling Method										Percent Cover		
		Density			Perpen- dicular				Parallel			Perpen- dicular		
		5-m x 5-m Regular	5-m x Random	4-m x Quadrat	4-m x Quadrat	Parallel Belt	Point- Centered	Transect Quarter	Line Intercept	Line Estimate	Belt	Transect	Belt	Transect
Upland	# Samples	25	25	37	170	196	6	47	93	193	135	—	—	—
	# Individuals	120	120	136	72	54	24	—	—	—	—	—	—	—
	Area*	625	625	592	170	196	—	792	93	193	135	—	—	—
	Time (min)	181	181	172	88	107	71	89	79	126	91	—	—	—
	E <sub>C</sub> **	19.04	30.65	20.50	15.20	16.05	7.66	13.35	13.00	18.90	14.82	—	—	—
Transition	# Samples	16	24	2	303	147	97	23	20	60	20	—	—	—
	# Individuals	119	179	14	96	89	388	—	—	—	—	—	—	—
	Area	400	600	32	303	167	—	368	20	60	20	—	—	—
	Time	345	397	110	205	179	620	136	54	123	130	—	—	—
	E <sub>C</sub>	113.58	50.88	13.73	34.77	78.37	55.42	27.37	12.32	17.54	27.61	—	—	—
Wetland	# Samples	8	4	32	310	123	45	11	50	70	80	—	—	—
	# Individuals	64	32	117	134	86	180	—	—	—	—	—	—	—
	Area	200	100	512	310	123	—	176	50	70	80	—	—	—
	Time	190	175	434	218	168	362	68	64	60	66	—	—	—
	E <sub>C</sub>	37.05	16.86	47.14	34.77	14.42	16.09	22.91	11.00	13.00	12.20	—	—	—

\* Area in  $m^2$  for all methods but line-intercept, which is in  $m$ .  
\*\* E<sub>C</sub> values shown are for sampling intensity with time requirements closest to 100 minutes.

Source: ESZ, 1981.

**Table 14**  
**Measured or Predicted Sampling Intensities Needed to Reach 15% SSI Constant Adequacy Levels (cm.)**  
**for Shrub Sampling Methods at Sites A and B**

Zone	Sampling Requirements to Reach CAI	Sampling Method						Sampling Method					
		Site A			Site B			Site A			Site B		
		4-m x 4-m	4-m x Random	Point- Centered Quarter	% Cover Line	4-m x Random	Point- Centered Quarter						
<b>Second Upland</b>													
# Samples	18	18	62*	20	—	—	—	—	—	—	—	—	—
# Individuals	249	227	248	—	20	—	—	—	—	—	—	—	—
Area†	288	288	—	—	90	—	—	—	—	—	—	—	—
Time (min)	144	137	—	90	—	—	—	—	—	—	—	—	—
E <sub>C</sub> **	24.39	20.98	58.59	12.10	—	—	—	—	—	—	—	—	—
<b>Upland</b>													
# Samples	15	20	14	60	—	5	20	403*	40	—	—	—	—
# Individuals	199	261	56	—	—	55	203	1612	—	—	—	—	—
Area	240	320	—	60	80	80	320	—	—	—	—	—	—
Time	126	146	163	174	162	282	1864	—	—	—	—	—	—
E <sub>C</sub>	17.03	38.29	60.04	36.01	2.64	63.79	27.98	12.62	—	—	—	—	—
<b>Transition</b>													
# Samples	55*	54*	20*	100*	—	18	18	46*	40	—	—	—	—
# Individuals	322	319	80	—	235	238	186	—	—	—	—	—	—
Area	880	864	—	100	288	288	—	—	—	—	—	—	—
Time	233	234	220	190	266	266	183	—	—	—	—	—	—
E <sub>C</sub>	38.84	26.99	63.74	25.04	25.58	3.15	18.10	9.46	—	—	—	—	—

(Continued)

\* Area in m<sup>2</sup> for all methods but line-intercept, which is in m.

\*\* E<sub>C</sub> values shown are for sampling intensity with time requirements closest to 100 minutes.

Table 14 (Concluded)

Sampling Requirements to Reach CL	Zone	Sampling Method						Site B					
		Site A			Site B			Site A			Site B		
		4-m x 4-m	4-m x Regular	Point-Center Random	% Cover -Line	4-m Quadrat	Point-Center Quadrat	4-m Regular	4-m Random	Point-Center Quadrat	4-m Regular	4-m Random	% Cover -Line
Wetland	# Samples	-	-	-	-	-	-	12	20	20	40	-	-
	# Individuals	-	-	-	-	-	-	146	203	80	-	-	-
	Area*	-	-	-	-	-	-	192	320	-	40	-	-
	Time (min)	-	-	-	-	-	-	218	262	167	44	-	-
	R <sub>C</sub>	-	-	-	-	-	-	37.06	24.43	15.80	11.02	-	-

\* Area in  $m^2$  for all methods but line-intercept, which is in  $m$ .

\*\* R<sub>C</sub> values shown are for sampling intensity with time requirements closest to 100 minutes.

Source: ESR, 1981.

When mean field sampling time is calculated for all sites and zones, those methods which are based upon cover estimates appear to be more efficient than density measurements. On the average, cover methods required only 36 percent of the mean field time required for all density methods and 48 percent of the mean time required for quadrat-based density methods.

220. The mean field sampling time per zone of each of the three cover-based methods varied from the mean of all methods by no more than 12 percent, indicating that there is a fairly consistent time requirement in the vicinity of 70 to 140 minutes for cover measurement regardless of method or zone (Table 15). Field sampling time ranges for density methods showed considerably more variation; however, in every instance but one (belt transect used in the upland zone), the time requirement per zone of each density-based method was higher than that of any of the cover-based methods (Table 15).

#### Accuracy

221. The evaluation of shrub sampling methods for accuracy did not yield the distinct patterns shown in the efficiency data. Substantial variation occurred among relative dominance patterns, both in relation to census data and among methods (Tables 16, 17, 18, and 19). The density methods appear to have yielded the most consistent and accurate species rankings, but no further pattern is apparent from the data.

222. Although the IS<sub>BC</sub> values in comparison to the census were generally higher for density methods than for cover, there remained considerable variation. In general, IS<sub>BC</sub> values seem to be linked to required field sampling time rather than to method. The values for the point-centered quarter method are the only values which do not seem to fit this pattern. The point-centered quarter method appears to require a substantially greater sampling time than other methods, while yielding no increase in accuracy.

**Table 15**  
**Mean Time Requirements of Generic Methods for Sampling Shrubs (Mean of Three Sites)**

Zone	Time Required (Minutes) to Reach Constant Adequacy Level (CAL)					
	Density Methods		Belt		% Cover Methods	
	Point	Quarter	Quadrats	Transsects	Line Intercept	Belt Transects
Upland	294	188	98	71	89	109
Transition	882	224	192	101	136	127
Wetland	234	257	193	103	68	74
<b>Mean--All Zones</b>	<b>470</b>	<b>223</b>	<b>162</b>	<b>92</b>	<b>98</b>	<b>103</b>

Source: ESE, 1981.

**Table 16**  
**Comparison of Relative Dominance\* of Representative Species of the Shrub Stratum at Site C, as Measured by Census and by  
 10 Sampling Methods. Also Shown are Similarity Values (ISG) of Each Method to the Census, and the Number of  
 Species that Each Method Erroneously Added or Omitted from Censused Community**

Zone	Species	Census	Sampling Method										% Cover	
			Density			Perpen-			% Cover					
			Regular	Random	5-m x 5-m	4-m x 4-m	Parallel	Belt	Point-Centered	Line	Inter-	Parallel		
Upland	<i>Sepium sebiferum</i>	23.1	23.1	23.1	27.3	18.2	45.8	4.0	18.3	13.4	13.4	20.3		
	<i>Brunnichia cirrhosa</i>	23.1	23.1	23.1	0.0	24.2	9.1	8.3	0.0	5.0	3.9	1.7		
	<i>Rosa bracteata</i>	12.0	12.0	12.0	27.3	24.2	9.1	0.0	46.6	9.5	8.7	6.8		
	<i>Ilex vomitoria</i>	7.4	7.4	7.4	0.0	0.0	0.0	8.3	0.0	0.0	1.6	3.4		
	<i>Diospyros virginiana</i>	1.9	1.9	1.9	0.0	3.0	4.5	12.5	0.0	6.9	7.9	5.1		
	<i>Aesculus parviflora</i>	0.9	0.9	0.9	0.0	0.0	4.5	0.0	0.0	0.0	0.0	5.1		
Transition	<i>Iva frutescens</i>	33.0	27.3	30.8	23.5	11.3	21.1	28.8	48.6	5.7	9.3	14.0		
	<i>Sabal minor</i>	19.0	19.0	19.7	17.6	21.1	5.3	0.0	24.9	11.2	21.7	23.7		
	<i>Baccharis halimifolia</i>	11.7	8.3	13.7	0.0	14.1	10.5	11.5	15.0	24.9	10.4	12.3		
	<i>Sapium sebiferum</i>	8.9	12.4	8.5	17.6	9.9	10.5	15.0	0.0	16.6	7.6	3.4		
	<i>Ampelopsis arborea</i>	1.7	1.7	0.9	0.0	2.8	0.0	0.0	0.0	3.8	0.0	2.1		
	<i>Campsis radicans</i>	0.6	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

(Continued)

\* Relative dominance expressed as percentage is based on relative density for density-based methods and on relative cover for cover methods.

Table 16 (Concluded)

Zone	Species	Census	Sampling Method						% Cover			
			Density			Point-Centerd			Line Intercept		Perpen-dicular Belt	
			Regular 5-m x	Random 5-m x	Regular 4-m x	Perpen-dicular 4-m x	Parallel Belt	Point-Centerd Quarter	Transect	Transect	Estimate	Intercept
Wetland	<i>Baccharis halimifolia</i>	47.9	50.9	63.0	59.1	36.3	19.2	60.0	43.5	65.5	38.2	21.9
	<i>Iva frutescens</i>	34.7	35.8	33.3	22.7	42.5	57.7	37.5	39.5	21.7	34.8	43.0
	<i>Sabal minor</i>	11.1	4.5	11.1	18.2	20.0	19.2	0.0	13.0	12.8	15.2	28.9
	<i>Myrica cerifera</i>	3.2	9.0	0.0	0.0	1.3	3.8	2.0	3.2	0.0	6.2	1.8
	<i>Rosa bracteata</i>	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0
	<i>Cephaelanthus occidentalis</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	4.4

\* Relative dominance expressed as percentage is based on relative density for density-based methods and on relative cover for cover methods.

Source: ESE, 1981.

**Table 17**  
**Indicators of Sampling Accuracy for 10 Shrub Sampling Methods. Similarity (ISPC)**  
**Based on Degree of Similarity to Census Values**

Zone	Species	Census	Quadrat	Sampling Method								% Cover	
				Density				% Cover					
				Regular 5-m x	Random 5-m x	Perpen- dicular 4-m x	Parallel Belt	Point- Centered	Point- Quarter	Line Cover	Inter- cept	Parallel Belt	Perpen- dicular Belt
Upland	ISPC Census	—	100.0	100.0	48.8	65.4	51.3	50.5	30.2	50.2	45.2	48.0	48.0
	# Species Added	—	0	0	0	0	0	1	0	2	0	0	0
	# Species Omitted	—	0	0	11	11	9	8	11	8	8	8	6
Transition	ISPC Census	—	89.4	93.1	57.2	74.9	58.6	58.5	65.7	49.2	51.3	69.4	69.4
	# Species Added	—	0	0	0	0	0	3	0	1	1	0	0
	# Species Omitted	—	2	3	9	4	7	7	10	6	6	5	5
Wetland	ISPC Census	—	90.3	92.3	81.9	83.4	68.2	84.6	93.3	69.6	87.2	69.5	69.5
	# Species Added	—	0	0	0	0	0	0	0	0	1	1	1
	# Species Omitted	—	1	2	2	1	1	2	0	3	1	1	1

\* Relative dominance expressed as percentage based on relative density for density-based methods and on relative cover for cover methods.

Source: ESE, 1981.

Table 18  
Comparison of Relative Dominance\* of Representative Species of the  
Shrub Stratum at Site B, as Measured by Four Sampling Methods.  
Also Shown is the Mean of the Similarity Values (ISBC)  
Comparing Each Method to all Other Methods

Zone	Species	Sampling Method			
		Density Methods		Z Cover Methods	
		Regular 4-m x 4-m	Random 4-m x 4-m	Point- Centered Quadrat	Line Quarter Intercept
		Quadrats	Quadrats	Quarter	Intercept
Upland					
	<u>Symplocos tinctoria</u>	27.3	24.1	36.3	21.8
	<u>Ilex vomitoria</u>	14.5	18.7	11.3	17.0
	<u>Itea virginica</u>	0.0	10.3	0.0	0.0
	<u>Styrax grandifolia</u>	0.0	9.9	3.8	0.0
	<u>Cyrilla racemiflora</u>	0.0	0.5	0.0	0.0
	<u>Carpinus caroliniana</u>	0.0	0.0	2.5	4.2
	ISBC (Mean)	70.3	71.9	66.4	66.7
Transition					
	<u>Ilex verticillata</u>	21.6	20.1	7.9	7.0
	<u>Cyrilla racemiflora</u>	5.1	11.4	1.3	4.8
	<u>Symplocos tinctoria</u>	12.5	10.9	19.7	12.6
	<u>Viburnum dentatum</u>	10.2	10.0	2.6	9.9
	<u>Clethra alnifolia</u>	0.0	1.5	1.3	1.8
	<u>Quercus nigra</u>	0.6	0.5	3.9	3.4
	ISBC (Mean)	62.6	61.2	47.0	57.4
Wetland					
	<u>Ilex verticillata</u>	71.2	67.5	30.0	42.3
	<u>Cephalanthus occidentalis</u>	2.7	9.9	12.5	15.5
	<u>Fraxinus caroliniana</u>	9.6	9.4	10.0	2.9
	<u>Cyrilla racemiflora</u>	9.6	6.9	8.8	7.7
	<u>Itea virginica</u>	2.1	1.5	13.8	0.0
	<u>Clethra alnifolia</u>	0.0	0.5	0.0	0.0
	ISBC (Mean)	68.5	72.3	60.3	64.7

\* Relative dominance expressed as percentage is based on relative density for density-based methods and on relative cover for line intercept.

Source: ESE, 1981.

Table 19  
Comparison of Relative Dominance\* of Representative Species of the  
Shrub Stratum at Site A, as Measured by Four Sampling Methods.  
Also Shown is the Mean of the Similarity Values (ISBC)  
Comparing Each Method to all Other Methods

Zone	Species	Sampling Method			
		Density Methods		Z Cover Methods	
		4-m x Regular Quadrats	4-m x Random Quadrats	Point-Centered Quarter	Z Cover Line Intercept
<b>Second Upland</b>					
	<u>Ilex vomitoria</u>	53.78	53.78	58.75	68.81
	<u>Brunnichia cirrhosa</u>	30.22	30.22	1.25	24.15
	<u>Rubus betulifolius</u>	5.33	5.33	0.00	0.00
	<u>Baccharis halimifolia</u>	4.00	4.00	11.25	0.00
	<u>Rosa bracteata</u>	0.00	0.00	1.25	0.00
	<u>Aesculus pavia</u>	0.88	0.88	6.25	0.29
	ISBC (Mean)	63.9	63.9	63.9	71.5
<b>Upland</b>					
	<u>Brunnichia cirrhosa</u>	25.93	25.93	15.00	34.64
	<u>Ilex vomitoria</u>	20.16	20.16	13.75	38.17
	<u>Myrica cerifera</u>	19.34	19.34	30.00	9.54
	<u>Ampelopsis arborea</u>	8.64	8.64	2.50	1.30
	<u>Sabal minor</u>	3.70	3.70	2.50	1.96
	<u>Smilax bona-nox</u>	0.14	0.14	0.00	4.05
	ISBC (Mean)	63.0	63.0	63.0	54.1
<b>Transition</b>					
	<u>Baccharis halimifolia</u>	29.41	29.41	25.00	11.60
	<u>Myrica cerifera</u>	21.85	21.85	20.00	25.06
	<u>Iva frutescens</u>	15.13	15.13	5.00	0.00
	<u>Brunnichia cirrhosa</u>	14.29	14.29	22.50	27.84
	<u>Ampelopsis arborea</u>	2.50	2.50	7.50	3.48
	<u>Daubentonia texana</u>	1.68	1.68	0.00	0.00
	ISBC (Mean)	62.4	62.4	71.9	61.5

\* Relative dominance expressed as percentage is based on relative density for density-based methods and relative cover for line intercept.

Source: ESE, 1981.

## Herbaceous Sampling Methods

### Variability and efficiency

223. Sixteen variations of herbaceous sampling methods were used for field evaluation of these methods. Because of the many variations in method and the high degree of variability in the resulting data, a direct comparison of specific results of all methods was impractical. This high variability of the raw data tended to mask any consistent trends among methods.

224. In order to clarify results, the methods were grouped by general type, and comparisons were made within these groups of types. The three general types of methods are the quadrat variations, the belt transect variations, and the cover estimate variations.

225. The quadrat methods consisted of using  $0.25\text{-m}^2$ ,  $0.50\text{-m}^2$ , and  $1.00\text{-m}^2$  sampling areas with square, rectangular, and circular shapes to sample vegetation. When the mean sampling requirements for these nine possible quadrat variations were computed for the ten individual zones sampled from Sites A, B, and C, there was such a high degree of variability that no consistent trends could be distinguished.

226. To facilitate further analysis, the quadrat methods were grouped by size and by shape. Table 20 shows the mean sampling requirements necessary to reach a 15-percent CAL for each size and shape of quadrat. In this table, the values shown for each sample size represent a mean of all shapes of quadrats utilized. The values shown for each shape of quadrat are based on a mean of three quadrat sizes. Also included for comparison are  $0.125\text{-m}^2$  quadrats (rectangular) as used on the belt transects.

227. Two-way analysis of variance (ANOVA) (Sokal and Rohlf, 1973) was used to test for significant differences among quadrat shapes and among zones within each study site. No significant

**Table 20**  
**Measured or Predicted Sampling Intensities Needed to Reach 15% SEM Constant Adequacy Levels (CAL)**  
**for Herbaceous Sampling Methods**

Site and Zone	Sampling Requirements to Reach CAL	Quadrat Size			Sampling Variations			Belt Transect Variations		
		Quadrat	Quadrat		Quadrat	Quadrat Shape		Quadrat	Circular	Contig- uous
			0.125-m <sup>2</sup>	0.25-m <sup>2</sup>		1.00-m <sup>2</sup>	Rectan- gular			
<b>Site A</b> <b>Second upland</b>	# stems sampled	124	176	247	181	223	339	43	124	-
	Area sampled (m <sup>2</sup> )	18	23	28	26	30	31	15	18	-
	Time (min)	113	222	215	122	205	241	83	113	-
<b>Upland</b>	# stems sampled	137	51	267	264	108	95	379	137	-
	Area sampled (m <sup>2</sup> )	11	17	23	18	24	16	17	11	-
	Time (min)	163	255	171	116	152	156	255	163	-
<b>Transi- tion</b>	# stems sampled	4413	4169	5045	9487	7935	5395	5372	4413	-
	Area sampled (m <sup>2</sup> )	13	20	24	40	38	27	19	13	-
	Time (min)	361	605	419	1569	1259	832	473	361	-
<b>Wetland</b>	# stems sampled	1055	3439	4311	6432	8887	3900	5494	1095	-
	Area sampled (m <sup>2</sup> )	1	5	8	15	12	10	7	1	-
	Time (min)	58	108	116	211	155	154	148	58	-
<b>Mean all zones</b>	# stems sampled	1442	1959	2468	4091	4238	2632	2822	1442	-
	Area sampled (m <sup>2</sup> )	11	16	21	25	26	21	15	11	-
	Time (min)	174	298	205	505	443	346	240	174	-

(Continued)

(Sheet 1 of 3)

Table 20 (Continued)

Site and Zone	Sampling Requirements to Reach CL:	Sampling Variations											
		Quadrat Size			Quadrat Shape			Belt Transect Variations					
		0.125-m <sup>2</sup>	0.25-m <sup>2</sup>	0.50-m <sup>2</sup>	1.00-m <sup>2</sup>	Square	Rectan-	Contig-	0.125-m <sup>2</sup>	Alternate	Contig-	0.125-m <sup>2</sup>	0.25-m <sup>2</sup>
Site B Upland	# stems sampled	324	910	1531	2281	1689	1561	1361	324	534	562	562	562
	Area sampled (m <sup>2</sup> )	5	6	11	13	12	11	7	5	6	8	8	8
	Time (min)	48	92	168	170	166	152	116	48	68	92	92	92
Transi- tion	# stems sampled	343	579	961	749	583	567	1140	343	225	420	420	420
	Area sampled (m <sup>2</sup> )	5	8	14	12	9	10	14	5	4	8	8	8
	Time (min)	51	116	194	183	126	194	173	51	48	69	69	69
Wetland	# stems sampled	210	123	89	83	124	149	89	210	166	328	328	328
	Area sampled (m <sup>2</sup> )	23	89	85	119	89	72	130	23	20	37	37	37
	Time (min)	212	687	687	1217	665	1055	672	212	242	242	242	242
Mean all zones	# stems sampled	292	537	860	1038	798	752	870	292	309	437	437	437
	Area sampled (m <sup>2</sup> )	11	34	37	48	37	31	50	11	10	18	18	18
	Time (min)	104	299	350	523	319	467	387	104	119	141	141	141
Site C Upland	# stems sampled	336	439	916	—	779	685	569	336	154	199	199	199
	Area sampled (m <sup>2</sup> )	6	9	16	—	14	13	11	6	2	3	3	3
	Time (min)	94	371	577	—	543	531	369	94	28	38	38	38

(Continued)

(Sheet 2 of 3)

Table 20 (Concluded)

Site and Zone	Sampling Requirements to Reach 90%	Quadrat Size						Sampling Variations						Belt Transect Variations					
		Quadrat			Quadrat			Quadrat			Quadrat			Quadrat			Quadrat		
		0.125-m <sup>2</sup>	0.25-m <sup>2</sup>	0.50-m <sup>2</sup>	1.00-m <sup>2</sup>	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat
Transition	# stems sampled	131	517	775	-	561	697	680	131	539	766								
	Area sampled (m <sup>2</sup> )	2	7	11	-	6	9	10	2	10	16								
	Time (min)	40	325	357	-	332	349	346	40	40	436								
Wetland	# stems sampled	2206	2235	4379	-	2911	3818	3192	2206	2074	2827								
	Area sampled (m <sup>2</sup> )	4	13	12	-	12	13	12	4	4	5								
	Time (min)	122	324	532	-	381	469	434	122	101	162								
Mean all zones	# stems sampled	894	1064	2023	-	1617	1734	1480	894	922	1264								
	Area sampled (m <sup>2</sup> )	34	95	13	-	11	12	11	4	5	8								
	Time (min)	85	340	489	-	419	450	376	85	133	212								

Source: ESE, 1981.

(Sheet 3 of 3)

differences ( $P = 0.05$ ) were found among quadrat shapes or among types of placement (random, regular, or stratified), whether based upon total field time, total area sampled, or the total number of stems counted.

228. The data were aggregated and tested with ANOVA for significant differences among quadrat sizes or among placement interactions within zones. Again, there were no significant interactions.

229. In order to obtain a better resolution of the effects of quadrat size and shape, if any, in the study sites, the results were re-aggregated by type of zone rather than by site. Figure 13 shows the relation of quadrat size to mean field sampling time for vegetation zones with various characteristics. In this analysis, the zones have been distinguished by their designations as upland, transition, or wetland and by the dominant vegetative strata found within the zone. Values shown are means from all zones of a similar type. For example, the values for herb-dominated wetlands are mean values from the marsh zones of Site A and C, while the values for tree-dominated transition zones are based on Site B, the only such zone sampled.

230. Figure 14 presents a summary of mean sampling time required for the same vegetation types using the three quadrat shapes. On the average, the circular quadrats appear to have slightly lower time requirements (although not statistically significant) than either square or rectangular-shaped quadrats.

231. Figure 15 shows the analysis of mean sampling time by zone for three variations of the belt transect methodology. Some variation exists in the data and in the patterns among methods; however, the basic belt method utilizing adjacent  $0.125\text{-m}^2$  quadrats appears to be the least time-consuming on the average. Eliminating every other quadrat from measurement, or aggregating adjacent  $0.125\text{-m}^2$  quadrats into  $0.25\text{-m}^2$  quadrats did not appear to result in a reduced field time requirement.

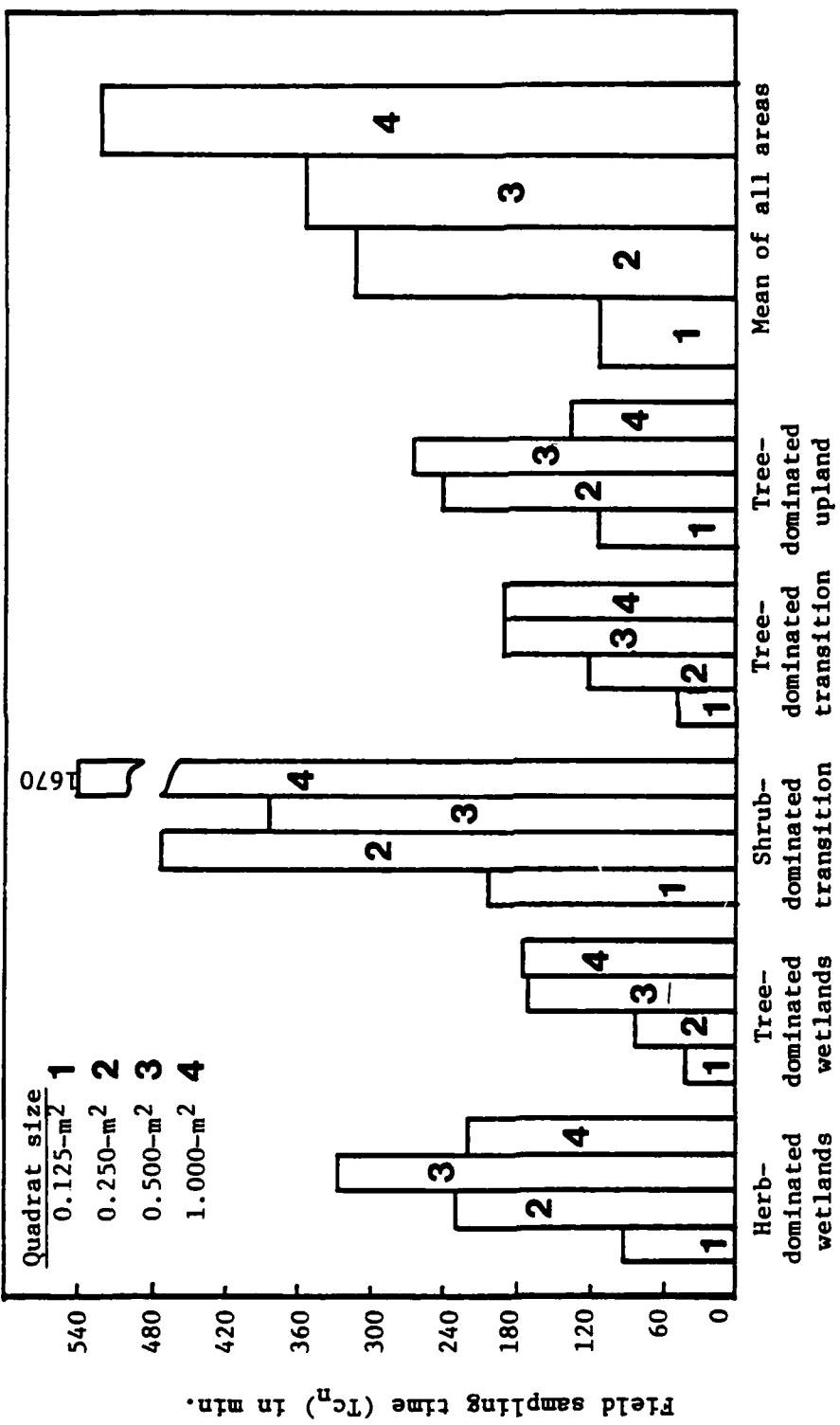


Figure 13. Mean field sampling time requirements for obtaining 15% SEM values for four sizes of quadrats for herbaceous stratum sampling. Results based on data from Sites A, B, and C.

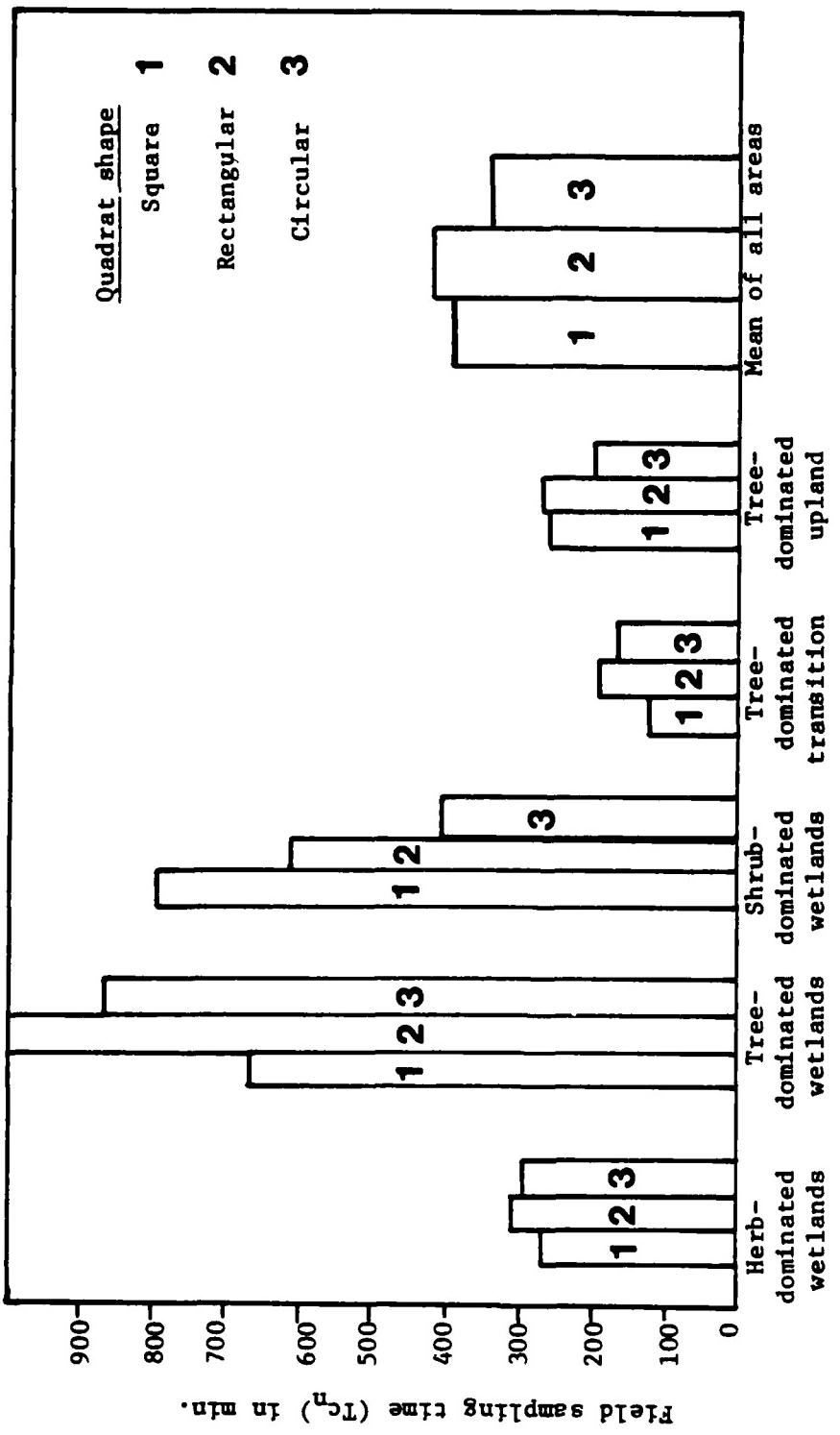


Figure 14. Mean field sampling time requirements for obtaining 15% SEM values for three shapes of quadrats for herbaceous stratum sampling. Results based on data from Sites A, B, and C.

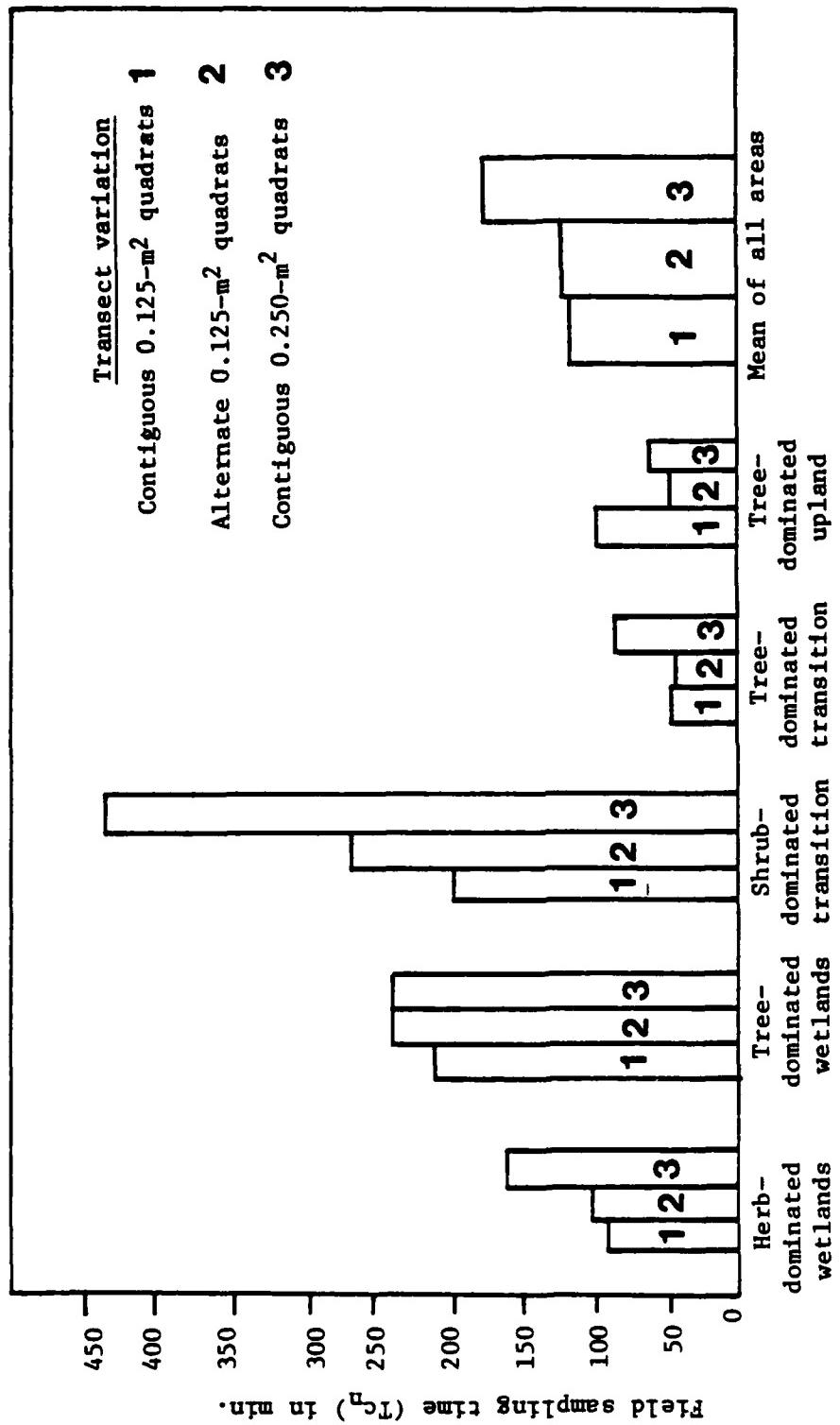


Figure 15. Mean field sampling time requirements for obtaining 15% SEM values for three variations of belt transect methods for herbaceous stratum sampling. Results based on data from Sites A, B, and C.

232. Table 21 shows the percentage of instances in which a particular variation of a methodology ranked first, second, or third in reducing field time. From this table, it would appear that, among the choices of quadrat shapes, the use of circular quadrats would be appropriate (ranked first or second among variations) at least 80 percent of the time. Among the belt transect variations, the use of either contiguous or alternate  $0.125\text{-m}^2$  quadrats would yield similar results.

233. Since the  $0.125\text{-m}^2$  quadrats appear to require the least field sampling time among density-based methods when oriented along a belt transect, this method was selected for further comparison to the methods based on cover analysis.

234. Figure 16 shows a comparison of the field time requirements for four cover estimation techniques to the time requirement of the continuous belt transect density-based method. The continuous line intercept method always was equal to or better than the belt transect in efficiency. The  $1\text{-m}$ -long line-intercept units or the cover estimations within  $1\text{-m}^2$  quadrats generally were similar in efficiency to the belt transects, but inferior to the continuous line-intercept method.

235. On the average, the point-intercept method was inferior to the belt transect and to each of the other cover estimation methods. The cause of this difference was an inordinately high requirement in the single, tree-dominated transition zone, which may be totally accounted for by random sample error. The data for the  $1\text{-m}$ -long line-intercept units also should be treated with care since no data are available from tree-dominated wetlands or from the tree-dominated transition zone. Thus, the mean time shown for this method is not consistent with data from other methods, and may be subject to alteration if additional data were to be collected.

Table 21  
Relative Performance of Herbaceous Stratum Sampling Method Based  
on Percentage of Instances in Which the Variation was  
Superior or Inferior to Other Variations

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A. Ranking of Quadrat Shapes

<u>Ranking Order</u>	<u>Percent Occurrence</u>		
	<u>Circular Quadrats</u>	<u>Square Quadrats</u>	<u>Rectangular Quadrats</u>
First	50	50	0
Second	30	10	60
Third	20	40	40
Mean rank	1.5	1.9	2.4

B. Ranking of Belt Transect Variations

<u>Ranking Order</u>	<u>Percent Occurrence</u>		
	<u>0.125-m<sup>2</sup></u> <u>Contiguous Quadrats</u>	<u>0.125-m<sup>2</sup></u> <u>Alternate Quadrats</u>	<u>0.25-m<sup>2</sup></u> <u>Contiguous Quadrats</u>
First	60	40	0
Second	20	60	20
Third	20	0	80
Mean rank	1.6	1.6	2.8

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Source: ESE, 1981.

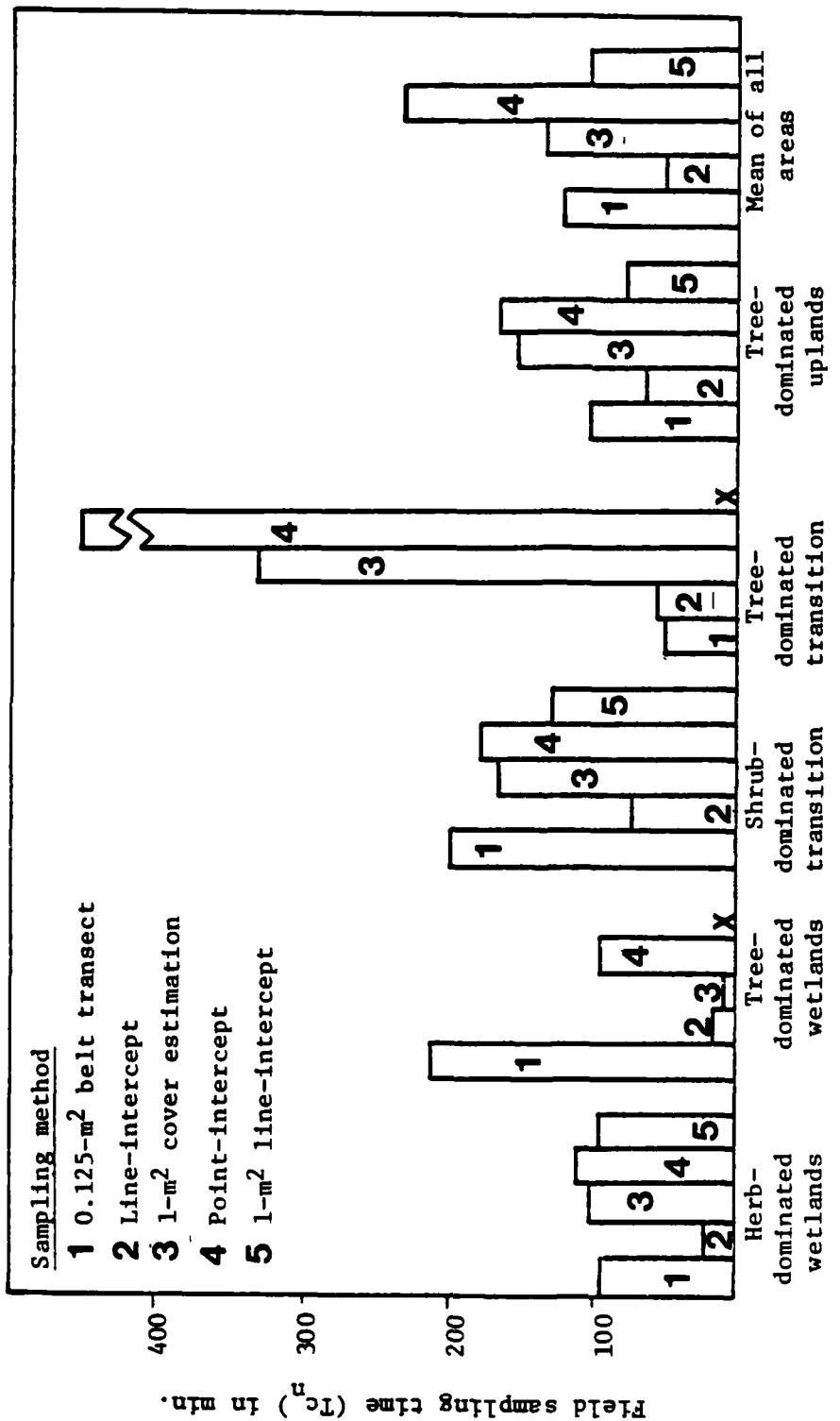


Figure 16. Mean field sampling time requirements for obtaining 15% SEM values for four cover-based methods compared to the belt-transect method for herbaceous stratum sampling. Results based on data from Sites A, B, and C. 'X' means no data for that type of zone.

### Accuracy

236. No census was made of herbaceous vegetation; however, when results of all density-based quadrat methods were combined, a sizable sampling intensity was obtained. This maximum sampling intensity ranged from 2.5 percent of total site area in Site A to 3.63 percent of total site area in Site B.

237. The results from this "maximum sample" were used as the basis against which the accuracy of all sampling methods was evaluated. For this evaluation, two variations of similarity indices were used. In addition to the quantitative variation ( $IS_{BC}$ ) of Sorenson's Index previously used, a second index value was computed. The original Sorenson's Index ( $IS_S$ ), which is based only on presence or absence of species in each sample, was also used as an index of how well each method predicts the species present. The quantitative index ( $IS_{BC}$ ) is a measure of how accurately each method predicts actual species dominance.

238. Figure 17 presents the similarity indices for each method, compared to the maximum sample. For both indices, high values indicate high degrees of accuracy. Because the  $0.25\text{-m}^2$  quadrats were a subsample of the maximum sample against which all methods were compared, the index values for this method are somewhat biased and are higher than values for most other methods. The values for the  $0.25\text{-m}^2$  quadrats thus may approximate the practical upper limits of the similarity indices when used to compare sample values to census values.

239. On a quantitative basis, most methods yielded similar index values between 55 and 65 percent. Index values based on species presence show considerably more variation. This pattern indicates that dominance is generally shared among relatively few species, such that values for four or five key species determine the index value. With the qualitative index ( $IS_S$ ), each species is weighted equally, and the presence of rare species has a greater impact on the index.

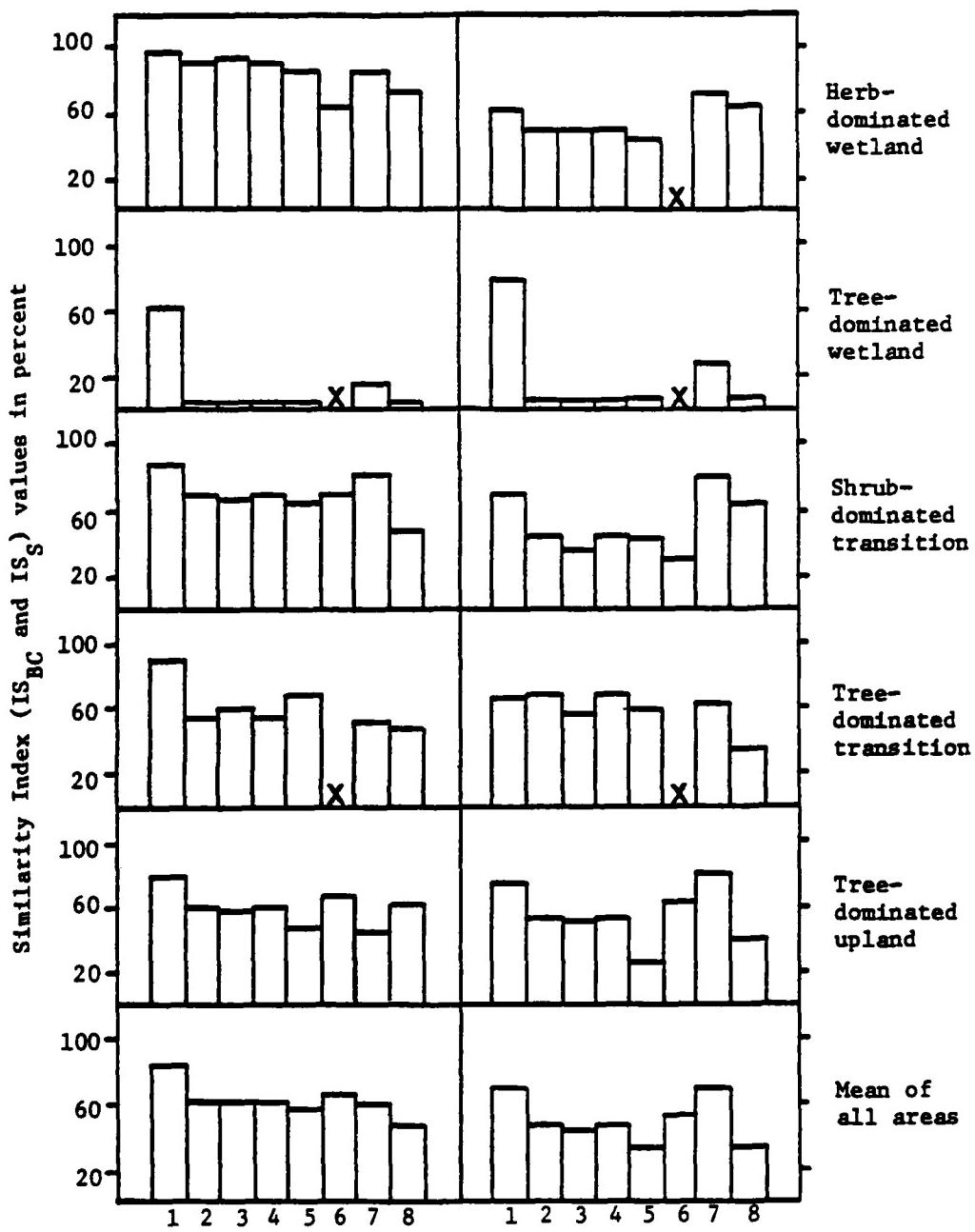


Figure 17. Accuracy evaluation of herbaceous stratum sampling methods. Degree of similarity to results from intensive sampling program, expressed as  $IS_{BC}$  quantitative similarity index (right) and  $IS_g$  qualitative similarity index (left). Methods shown are:

(1) $0.250\text{m}^2$ quadrat	(5) Line-intercept
(2) $0.125\text{m}^2$ belt transect	(6) 1m unit line intercept
(3) $0.125\text{m}^2$ alternate unit belt transect	(7) Cover estimation
(4) $0.250\text{m}^2$ unit belt transect	(8) Point intercept

240. The quadrats, the  $1-m^2$  cover estimation, and the  $1-m$  line-intercept were the most accurate. However, as mentioned, these methods may have been biased since sample location was not independent of that used for the maximum sample. The time required for these methods compared to the equivalent line or belt methods (i.e., quadrat versus belt transect; cover estimation or  $1-m$  line-intercept unit versus continuous line-intercept) was generally about twice as long.

241. Therefore, it was determined that the additional accuracy of these methods did not justify the additional time requirements, and a combination of belt transect and continuous line-intercept methods has been selected as the best method for this region.

242. Tables 22, 23, and 24 show the relative importance of the six most dominant species in each zone. The predicted relative importance of each species based on various sampling methods is also shown.

243. These tables indicate that in very few cases does any method accurately estimate the true relative importance of more than one or two of the dominant species in a zone. Only in the marshes where just one or two species are dominant do the herbaceous methods have good predictive ability at the sampling intensities used. Again, there is a bias toward the quadrat methods both because of placement and because of the differences in dominance as measured by density and by cover.

#### Discussion and Analysis of Phase I Results

##### Overstory sampling methods

244. Overstory efficiency. The cover estimation and distance (plotless) methods appear to be most efficient for sampling in Louisiana transition zones (Figures 6 and 7) because of the low time requirements for obtaining data with less than a

**Table 22**  
**Comparison of Relative Dominance\* of Representative Species of the Herbaceous Stratum**  
**at Site A, as Measured by an Intensive Sampling and by Six Sampling Variations**

Zone	Species	Sampling Method					
		Maximum Sample	0.25-m <sup>2</sup> Quadrat	0.125-m <sup>2</sup> Belt Transect	0.125-m <sup>2</sup> Belt Transect	0.25-m <sup>2</sup> Belt Transect	Line-Intercept Transect
<b>Second upland</b>							
	<i>Smilax bona-nox</i>	31.67	4.18	9.17	11.11	9.17	12.96
	<i>Oplismenus setarius</i>	19.17	35.56	12.66	9.52	12.66	5.09
	<i>Brunnichia cirrhosa</i>	18.06	24.27	26.20	32.54	26.20	31.94
	<i>Ilex vomitoria</i>	11.67	15.90	37.55	38.10	37.55	4.95
	<i>Stenotaphrum secundatum</i>	7.22	7.53	0.00	0.00	0.00	46.04
	<i>Smilax pumila</i>	4.17	0.00	0.00	0.00	0.00	0.99
							0.50
<b>Upland</b>							
	<i>Anisosticus capreolata</i>	20.59	22.73	0.53	1.05	0.53	0.00
	<i>Brunnichia cirrhosa</i>	13.03	29.09	60.42	53.68	60.42	58.82
	<i>Amelanchier arborea</i>	11.34	13.64	14.44	13.68	14.44	9.74
	<i>Cyperus iria</i>	9.66	0.00	0.00	0.00	0.00	0.00
	<i>Stenotaphrum secundatum</i>	9.24	0.00	2.14	3.16	2.14	2.05
	<i>Smilax bona-nox</i>	8.82	10.91	8.02	7.37	8.02	14.36
							4.27
<b>Transition</b>							
	<i>Spartina patens</i>	48.10	33.99	74.47	76.57	74.47	53.06
	<i>Eleocharis tuberosa</i>	21.18	28.95	0.13	0.04	0.13	0.00
	<i>Juncus roemerianus</i>	12.78	14.75	9.73	9.03	9.73	22.96
	<i>Panicum virgatum</i>	7.25	9.91	3.72	4.80	3.72	0.00
	<i>Cyperus iria</i>	3.69	4.19	0.00	0.00	0.00	0.00
	<i>Brunnichia cirrhosa</i>	1.52	1.19	1.39	0.74	1.39	2.55
							0.89
<b>Wetland</b>							
	<i>Spartina patens</i>	98.76	100.00	100.00	100.00	100.00	99.18
	<i>Juncus roemerianus</i>	1.20	0.00	0.00	0.00	0.00	0.00
	<i>Ipomoea sagittata</i>	0.04	0.00	0.00	0.00	0.00	0.01

\* Relative dominance expressed as percentage is based on relative density for density-based methods, and on relative cover for cover-based methods.

Source: ESE, 1981.

**Table 23**  
**Comparison of Relative Dominance\* of Representative Species of the Herbaceous Stratum  
at Site B, as Measured by an Intensive Sample and by Eight Sampling Variations**

Zone	Species	Sampling Method							
		Maximum Sample	0.25-m <sup>2</sup> Quadrat	0.125-m <sup>2</sup> Quadrat	0.125-m <sup>2</sup> Transect	0.25-m <sup>2</sup> Belt	Line-Belt Intercept	Point Transect Intercept	1-m <sup>2</sup> Cover Estimate
<b>Upland</b>									
	<i>Mitchella repens</i>	89.03	92.30	87.40	74.25	77.49	74.25	48.26	38.90
	<i>Gramineae sp.</i>	3.37	1.86	3.50	0.12	0.00	0.12	0.00	2.80
	<i>Gelsemium sempervirens</i>	2.40	1.99	2.57	5.45	3.39	5.45	3.30	2.80
	<i>Quercus</i> seedlings	1.84	1.37	2.45	6.15	5.25	6.15	5.50	2.40
	<i>Symplocos tinctoria</i>	0.65	0.50	0.93	1.16	1.09	1.16	3.85	5.60
	<i>Ilex vomitoria</i>	0.65	0.50	1.40	4.06	2.95	4.06	6.61	0.00
<b>Transition</b>									
	<i>Mitchella repens</i>	35.96	60.75	55.36	62.03	68.10	62.03	42.47	20.00
	<i>Arundinaria gigantea</i>	13.03	0.53	5.41	6.87	0.00	6.87	3.23	45.93
	<i>Ilex vomitoria</i>	12.93	0.18	0.79	0.96	5.45	0.96	5.54	31.40
	<i>Elephantopus tomentosus</i>	9.19	0.00	4.96	0.00	0.00	0.00	0.00	0.74
	<i>Gelsemium sempervirens</i>	5.56	12.43	9.13	3.12	3.64	3.12	4.16	8.60
	<i>Quercus</i> seedlings	4.65	3.55	0.11	5.52	4.46	5.52	10.16	0.00
<b>Wetland</b>									
	<i>Cyperaceae</i>	40.00	15.81	15.81	0.00	0.00	0.00	0.00	0.00
	<i>Arundinaria gigantea</i>	29.23	63.72	63.72	0.00	0.00	0.00	0.00	0.00
	<i>Smilax bona-nox</i>	6.92	2.79	2.79	0.00	0.00	0.00	0.00	0.00
	<i>Hypericum fasciculatum</i>	5.38	2.33	2.33	0.00	0.00	0.00	0.00	0.00
	<i>Nyssa aquatica</i>	5.00	4.65	4.65	0.00	0.00	0.00	0.00	0.00
	<i>Smilax pumila</i>	3.08	1.86	1.86	0.00	0.00	0.00	0.00	0.01
	<i>Lemna minor</i>	--	--	--	--	--	--	97.56	0.02
								97.80	98.83

\* Relative dominance expressed as percentage is based on relative density for density-based methods, and on relative cover for cover-based methods.

Source: ESE, 1981.

**Table 24**  
**Comparison of Relative Dominance\* of Representative Species of the Herbaceous Stratum at Site C,  
 as Measured by an Intensive Sample and by Eight Sampling Variations**

Zone	Species	Maximum Sample	0.25-m <sup>2</sup> Quadrat	Sampling Method							
				0.125-m <sup>2</sup> Belt	0.125-m <sup>2</sup> Quadrat	0.25-m <sup>2</sup> Belt	0.25-m <sup>2</sup> Transect	Line-Intercept Transect	Random Line Transect	Point Intercept Transect	1-m <sup>2</sup> Cover Estimate
<b>Upland</b>											
	<i>Stenotaphrum secundatum</i>	81.32	79.48	59.21	52.51	59.21	52.12	59.38	52.17	44.22	
	<i>Lycopus virginicus</i>	6.73	7.21	17.98	17.06	17.98	17.69	0.78	7.25	5.31	
	<i>Gramineae</i>	3.83	3.88	0.00	0.00	0.00	0.00	6.25	0.00	8.17	
	<i>Brunnichia cirrhosa</i>	3.60	3.51	5.56	6.02	5.56	2.59	1.56	2.90	0.50	
	<i>Eryngium yuccifolium</i>	1.16	1.11	1.75	1.67	1.75	0.00	15.63	13.04	10.97	
	<i>Campsipus radicans</i>	0.58	0.92	4.24	6.02	4.24	24.06	4.69	11.59	1.80	
<b>Transition</b>											
	<i>Alternanthera philoxeroides</i>	46.31	48.47	61.43	51.09	61.38	38.64	42.94	51.61	40.39	
	<i>Spartina patens</i>	35.74	39.97	18.83	28.99	16.38	29.35	23.93	12.90	25.25	
	<i>Stenotaphrum secundatum</i>	8.51	0.00	4.48	0.00	2.41	2.80	1.02	0.00	3.83	
	<i>Ipomoea sagittata</i>	1.80	1.70	2.69	1.45	0.34	4.42	0.61	6.45	3.36	
	<i>Brunnichia cirrhosa</i>	1.29	1.53	1.35	3.26	5.00	3.98	3.68	0.00	1.29	
	<i>Lycopus virginicus</i>	1.29	1.53	2.24	1.09	0.00	0.42	0.00	0.00	0.00	
<b>Wetland</b>											
	<i>Spartina patens</i>	59.82	59.04	61.19	72.61	61.19	45.94	34.31	60.87	47.26	
	<i>Alternanthera philoxeroides</i>	22.28	22.19	8.85	6.06	8.85	17.37	29.90	13.04	22.41	
	<i>Fleocharis tuberosa</i>	12.77	13.06	27.71	16.57	27.71	11.34	6.86	0.00	2.32	
	<i>Sagittaria falcata</i>	2.14	2.15	1.02	1.26	1.02	10.92	25.00	0.00	27.12	
	<i>Mollugo verticillata</i>	1.87	2.41	0.00	1.53	0.00	0.00	0.00	0.00	0.00	
	<i>Ipomoea sagittata</i>	0.32	0.33	0.96	0.85	0.96	9.80	3.92	17.39	0.81	

\* Relative dominance expressed as percentage is based on relative density for density-based methods, and on relative cover for cover-based methods.

Source: ESE, 1981.

15-percent SEM. Circular quadrats appear to be the most efficient of the quadrat methods.

245. The results of these quadrat studies are comparable to those reported by Bormann (1953) and Lindsey et al. (1958) in other parts of the country. Lindsey et al. (1958) presented results based upon field sampling time, and showed that circular plots using a rangefinder/variable radius combination were 30 to 40 percent more efficient than square plots.

246. Table 25 compares the calculated minimal area which would need to be sampled, as determined from the results of Bormann (1953), Lindsey et al. (1958), and the ESE studies at Sites A and B in Louisiana. To obtain this comparison, Bormann's data were converted to a 15-percent SEM base using Equation (8) found on Page 85. Consistent trends of these data indicate that:

- a. Adequate sampling for basal area determinations requires a sampling intensity that is two to six times greater than that required for density determinations.
- b. No significant and consistent differences in the required sampling area occur between circular- and other-shaped quadrats. Therefore, the increased efficiency of circular quadrats must be due to a reduction of sampling time per area, rather than to a reduction of required area.
- c. Orientation of rectangular quadrats perpendicular to elevational gradients is slightly more efficient than parallel orientation, although no statistical significance was found.
- d. The minimal required sampling area varies greatly depending on the specific site and on the density of the population sampled.

247. Examination of Table 25 indicates that differences among sites or populations appear to be proportional to the density of the sampled population. In order to evaluate the factors which may be influencing the minimal sampling area, regression analyses were made relating minimal sampling areas to various vegetative parameters. Regressions were run using total density, total cover, and species number per zone as the

**Table 25**  
**Minimum Sample Area ( $m^2$ ) Required to Attain a 15-Percent SEM for**  
**Total Density as Determined by Three Studies**

Investigator	Location	Estimated Density of Sampled Population (stems/ha)	Approximate Sampling Quadrat Dimensions					
			10-m x 10-m		5-m x 5-m		10-m x 20-m Circle	
			10-m x 5-m	5-m x 5-m	10-m x 20-m Circle	Perpendicular	Parallel	Circle
<b>Overstory density</b>								
Lindsey <i>et al.</i>	Indiana	70	4,590	—	4,590	—	—	—
ESE	Site A	547	2,000	2,130	2,430	2,800	3,333	3,140
ESE	Site B	1,358	500	700	600	660	660	1,000
<b>Overstory total basal area</b>								
Bormann	North Carolina	1,020	1,410	2,260	—	1,180	1,280	—
Lindsey <i>et al.</i>	Indiana	70	8,340	—	8,340	—	—	—
ESE	Site A	547	9,700	8,000	9,000	5,200	6,000	9,600
ESE	Site B	1,358	3,130	3,000	3,050	1,660	1,800	5,000

Sources: Lindsey *et al.*, 1958.  
 Bormann, 1953.  
 ESE, 1979.

independent variables. Figure 17 shows the linear regression lines (which were the best fit among linear, logarithmic, power, and exponential equations) relating required sample area to density of the sampled population based upon a composite of data from all quadrat methods.

248. Correlation coefficients indicate that the required minimal sampling area is indeed highly dependent upon population density. Linear regression lines for each of the individual quadrat dimensions (e.g., 10 m by 10 m) all were found to occur within the shaded areas (shown on Figure 18) delineated by the 95-percent confidence limit for the composite regression. Therefore, it appears that the differences among methods are minimal, and that by using the upper confidence limit shown on Figure 18 as a criterion of minimal sampling area, adequate sampling intensities for any of the quadrat methods can be estimated for any population density. Regression equations for each of the individual methods can be found in Appendix B. No correlation to either cover or species number was found.

249. ESE data support Bormann's conclusion that long, narrow, rectangular quadrats with dimensions over 20 m are most efficient in terms of total area sampled; however, for most transition zone determinations in Louisiana, such large plots will have limited utility. Many of these transitional areas are less than 20 m wide and lack lateral homogeneity over long distances. Therefore, space limitations will probably limit the possible number of these larger (over 100-m<sup>2</sup>) quadrats to levels below those needed for a 15-percent CAL.

250. Bourdeau (1953) used Bormann's data to compare the accuracies of random, regular, and stratified random quadrat placement. Using total sample areas of about 3 to 33 percent of stand area, Bourdeau found that random sampling was almost as accurate as regular sampling, and that stratified random sampling was always superior to random sampling. Because of the advantages

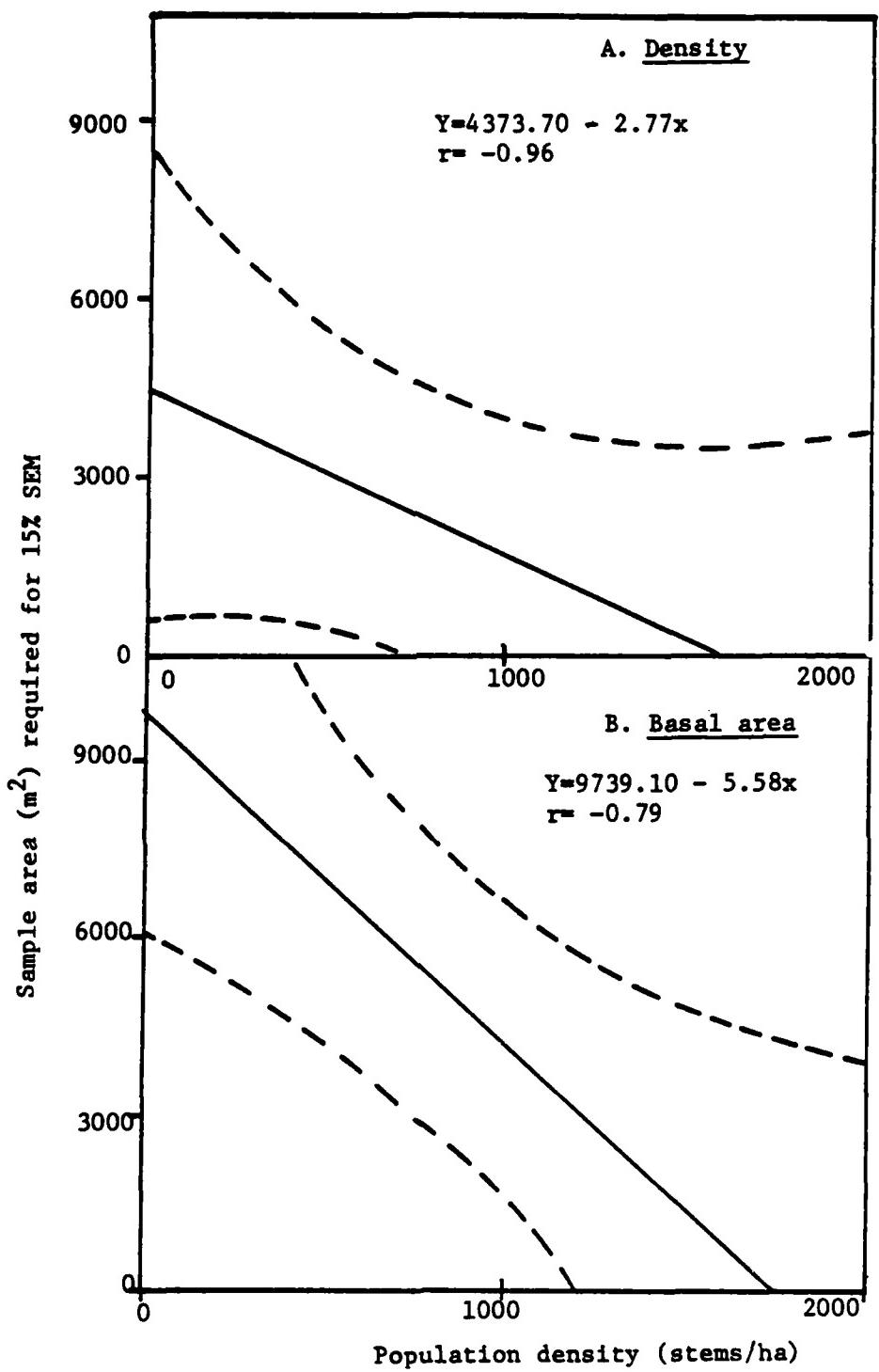


Figure 18. Predicted total area required to sample overstory basal area and density at 15% SEM level. Quadrat data from Sites A,B, and C. Shown with 90% confidence limits.

of using simple probability statistics, he concluded that stratified random sampling is the preferred alternative.

251. Bourdeau's variations in SEM among methods tested were relatively small compared to the magnitude of sampling error within each method. Results of the ESE study (see Figure 8) also indicate that it is difficult to establish significant or consistent differences among placements under field conditions, and that stratified random sampling is preferred where possible.

252. Cottam and Curtis (1956) evaluated several distance measures in four natural stands in Wisconsin and in one artificial population. Their results indicated that sample sizes of from 26 to 38 points were required for a 10-percent SEM using the point-centered quarter method. In the ESE study of two Louisiana sites, it was found that sample sizes of 20 to 41 points per zone were adequate. Figure 19 shows the linear regression for a combination of ESE data and those of Cottam and Curtis.

253. Although the point-centered quarter method is based on theoretical density concepts, the field efficiency data indicate that, in application, this method is less influenced by population density than are quadrats. This conclusion is not unreasonable, since the number of trees sampled per point remains constant regardless of density, whereas the number of trees sampled per quadrat area increases as density increases. Ultimately, quadrat adequacy is a function primarily of the number of stems sampled, whereas distance measure adequacies are a function of the pattern or spacing of trees.

254. The wandering quarter method has not been thoroughly evaluated for efficiency in the literature, although Catana (1963) has used it in studies of aggregation. The results from ESE's limited use of this method are not sufficient to adequately establish its efficiency compared to other distance methods. However, the method is rapid, convenient, and easy to apply, and therefore should be considered for further study.

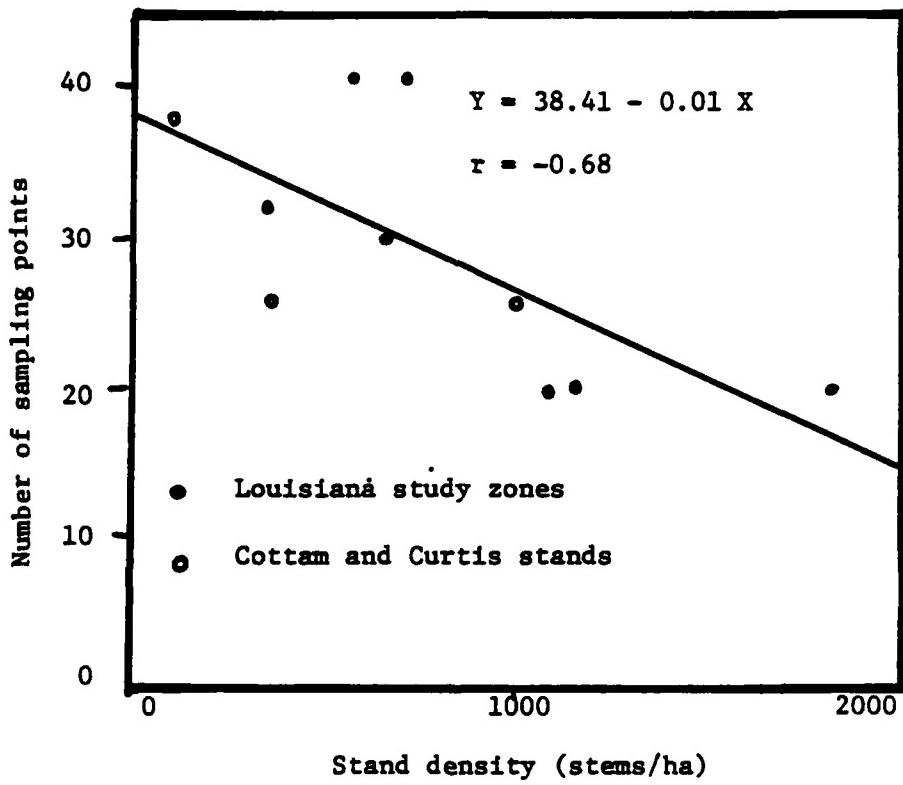


Figure 19. Total sampling effort (in number of sampling points) which would be required to sample overstory density by the point-quarter method with a 15-percent SEM level, as predicted by linear regression of data from Sites A and B and from Cottam and Curtis (1956).

255. Line-intercept cover estimation methods for trees have been analyzed extensively (Buell and Cantlon, 1950; Woodin and Lindsey, 1954; Lindsey, 1955), primarily on conifer stands. The usual method consists of measuring the canopy projection of each species over a transect line and calculating actual cover over the entire transect, which functions as a single sampling unit. The SEM is then computed on the basis of several transects. By this method, several transects would be needed, since the SEM is a function of sample size. Woodin and Lindsey (1954) and Lindsey (1955) found that such transects should be about 182 m (600 ft) in length and that eight transects constitute an adequate sample.

256. For this study, the method was modified to use presence of cover on 1-m intervals of each transect as separate sample units. This modification has the following advantages:

- a. Presence is more readily estimated than actual percent cover.
- b. Each 1-m unit can be considered a sampling unit, so that estimated cover and SEM can be computed from data from a single transect, if necessary.
- c. Consequently, the modification is better suited than the original line-intercept technique for use in areas with limited linear directions (e.g., transition zones) and when limited sampling time is available.

257. Since ESE's modification is an extension of the point-intercept principle, it does suffer from the disadvantages of point-intercept methods. In particular, the estimate of sample size is not independent of unit size. If the interval (1-m) were changed, the estimated percent cover values also would change. Generally, as the unit size decreases, the estimated percent cover decreases (Whitman and Siggeirsson, 1954). Because of these limitations, this modification should be used for relative rather than absolute cover determination, and for comparative purposes.

258. The field sampling time necessary to reach a specified CAL was significantly shorter for both cover estimation methods than for any method measuring density or basal area. The line-intercept modification was found to be the most efficient sampling method for determining vegetative dominance.

259. Overstory accuracy. Only rarely has accuracy of method been treated in the field. Cottam and Curtis (1956) compared census values with mean total density and basal area as measured by quadrat and distance methods. They reported results from three stands in which calculated total density was within an average of 4.5 percent of census value for quadrat methods and 5.3 percent for the point-quarter method. Basal area-per-acre values averaged within 3.0 percent and 9.0 percent, respectively, of census values.

260. Figure 20 shows best-fit regression equations from ESE's Louisiana data, comparing the calculated total density or cover of various methods to the true density value as determined by census. These values are computed from the six zones of Sites A and B. Figure 19 shows that, except for the 200-m<sup>2</sup> circle, all of the quadrat methods can be expected to yield total density values within about 8 percent of true census value. The high correlation coefficients (*r*) indicate that the relationship holds at all population densities.

261. At higher population densities, both the 200-m<sup>2</sup> circle and the point-quarter method tended to overestimate total density by large amounts, indicating that at high population densities, these methods generally are inaccurate.

262. Whereas all of the density-based methods tended to follow linear relationships, the best-fit regression for cover-based methods was found to be of the power function,  $Y = bx^m$ , which allows the rate of increase in total cover to decline as density increases. The correlation of estimated cover value to

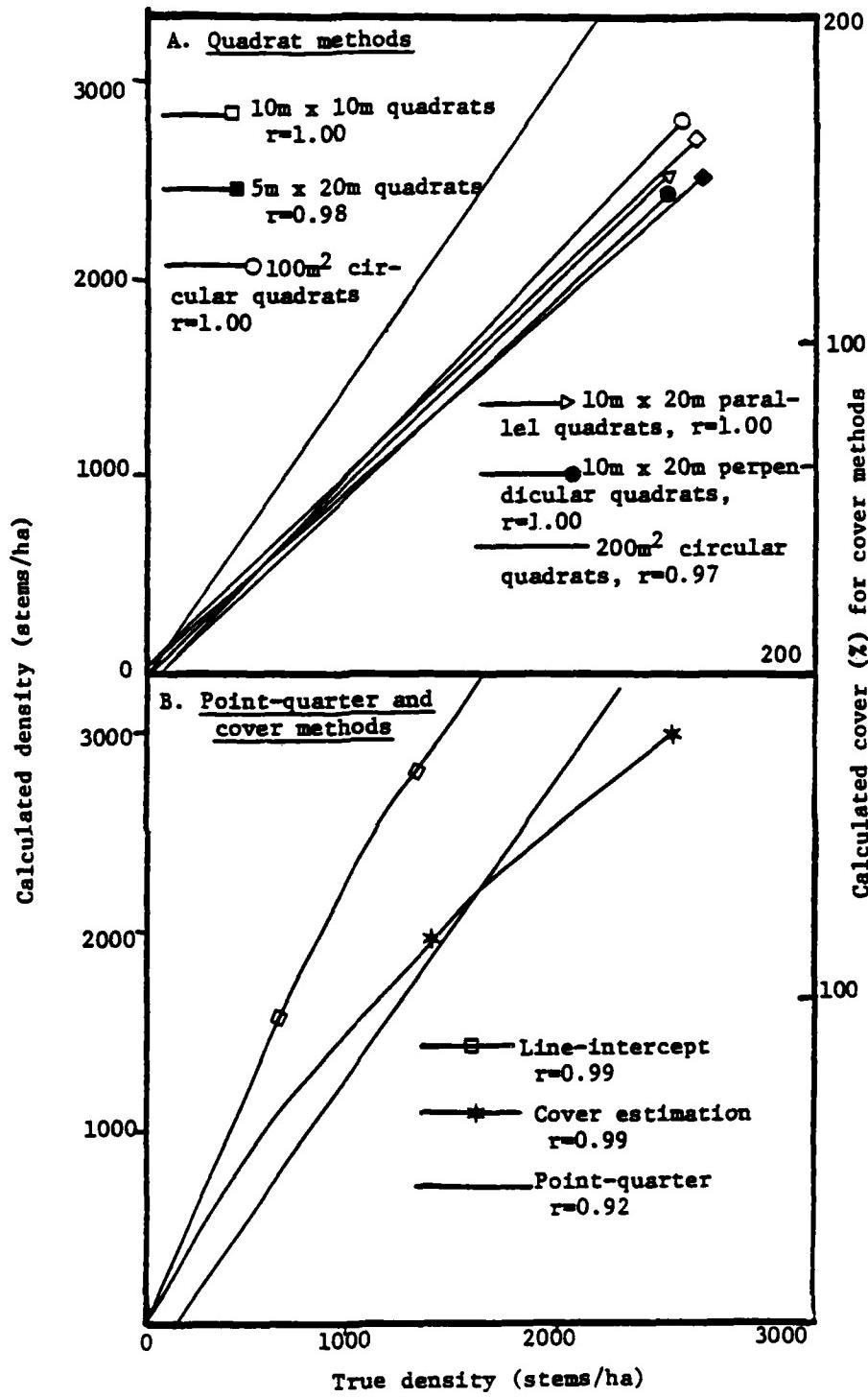


Figure 20. Predicted total stand overstory density and cover values compared to true density values from census of Sites A and B.

total density was found to be high over the range of values encountered.

263. ESE's modification of the line-intercept method gave substantially higher estimates of total cover than did the qualitative cover estimation, although the degree of correlation to total density was equally high. Since this line-intercept modification is dependent upon sample unit size, it would be possible to lower the slope of the regression line to approximate that of the cover estimate by reducing the unit size. For example, a reduction of unit size from 1.0 m (3.3 ft) to 0.5 m (1.6 ft) would probably calibrate the method to ESE's cover estimate values.

264. A second, often useful indicator of accuracy is the similarity index (IS). In cases where the true species composition of a stand is known from census values, the species composition estimated from the sample can be compared to the species composition of the census by an IS. The IS is a tool which can also be used to distinguish between two or more transitional zones on the basis of species composition and dominance, if the accuracy of the sample data is adequate. When using IS values for such comparisons, it is recommended that the sample values have IS values of at least 80 percent when compared to census values; that is, under test conditions, the sample data should be able to give at least an 80-percent IS value when compared to importance values from census data.

265. Numerous regression equations were computed for overstory data based upon sample results from Sites A and B. The relationship of  $IS_{BC}$  values compared to census data for total stand density and species number was evaluated for each method. In general, the correlation coefficient ( $r$ ) values were very low, indicating that for most methods the accuracy of IS values could not be readily predicted based on known density or species number. However, the equations do show that IS values appear to be greater

than 80 percent accurate under virtually all density and species number conditions for all of the quadrat methods.

266. The distance methods showed some rather high correlation coefficients (0.13 to 0.99) in relation to both density and species number. Accuracy appeared to increase under conditions of high density and low species number. Cover-based methods appeared to be most accurate when both density and species number were high. However, both distance and cover methods were predicted to yield accuracies below 80 percent under virtually all conditions. The regression equations and correlation coefficients are listed in Appendix B.

267. A third way to evaluate accuracy of method is to compare the calculated IV or relative dominance to that computed from census data. Figure 21 shows these relationships as calculated from the six most important species of each of the six zones of Sites A and B ( $n = 36$ ). When expressed as a linear regression relationship, all of the  $200\text{-m}^2$  quadrat combinations yield average IV values within 10 percent of the true (census) value. All of the  $100\text{-m}^2$  quadrats yield values within 13 percent of the true value.

268. The point-quarter and cover methods consistently tend to underestimate the IV of the dominant species (Figure 20b). In the case of the point-quarter method, a high proportion of species in an area is often omitted. When a dominant species is represented by only a few, large individuals, the chance of underestimating that species is high. The point-quarter method also tends to include species which are actually present only outside of the zone which is being sampled. Therefore, if the zone is rather narrow, as at Site B, the importance of peripheral or minor species may be overestimated, thus reducing the IV of the dominant species. Such results will tend to obscure distinctions between zones.

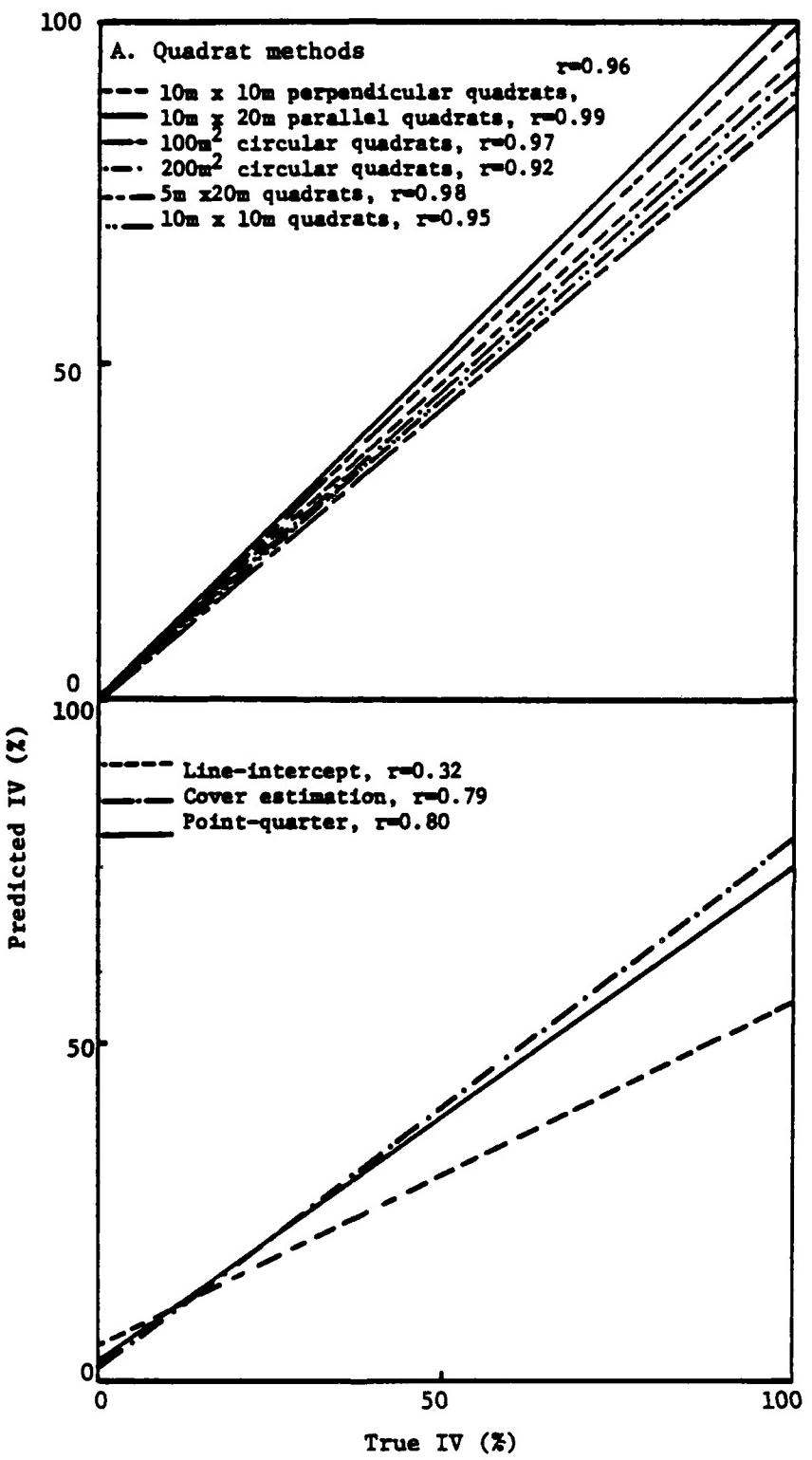


Figure 21. Predicted Importance Value for any over-story species compared to true Importance Value as determined from census data from Sites A and B

269. Cover values also may be influenced by the inclusion of trees which are not rooted within the zone, but whose canopies may overhang the zone, leading to similar problems in zone distinction. A second reason for the low IV for dominant species is that several possible dominants of the region, such as loblolly pine and bald cypress, may have rather small crown coverage in relation to trunk size. Therefore, cover methods may underestimate the importance of these species and may overestimate that of smaller, more spreading species.

270. Summary. In summary, the 100 m<sup>2</sup> circular quadrats offer the most efficient and accurate method for density and basal area determinations in most cases. The line-intercept cover modification can be used to supplement the density-based methods to provide a balanced species composition evaluation.

#### Shrub sampling methods

271. Shrub efficiency. It was mentioned previously that the cover-based methods were found to be more efficient than density-based methods in reducing variability and in reaching a specified CAL for total stand density or cover. Table 26 shows that the average time required to sample shrubs by cover-based methods at one site is only 39 percent of the time required by density-based methods.

272. Another useful indicator of efficiency is based upon the accuracy-time relationship. In cases in which census values are known, such as at Site C, an IS can be computed for each sampling method. The IS compares the sample species composition to that of the census. Table 26 shows the estimated minimal time required to obtain two levels of IS values, based on results from Site C. These values are only approximations, as indicated by the low correlation coefficients of the regression equations.

273. This accuracy-time (IS) relation shows a similar pattern to the variability-time (SEM) relationship. Cover methods

**Table 26**  
**Minimum Mean Field Sampling Time Requirements (Minutes) for Upland, Transition,  
 and Wetland Zones, as Well as Entire Sites to Achieve Specified Standards  
 of Efficiency and Accuracy (Based on Data from Site C)**

Specified Level of Performance	Required Field Sampling Time (min)					
	Density-Based Methods			Cover-Based Methods		
	Upland Zone	Transition Zone	Wetland Zone	Site Total All Zones	Upland Zone	Transition Zone
Sampling time required to reach 15-percent CAL	133	309	261	703	96	111
Sampling time required to reach 100-percent IS	225	2,470	1,299	3,994	772	366
Sampling time required to reach 80-percent IS	165	930	586	1,681	533	242
Regression curve for IS:time relation	$Y=24.9+$ $0.33x$ $r=0.69$	$Y=67.9+$ $0.13x$ $r=0.16$	$Y=86.2-$ $0.11x$ $r=-0.15$	--	$Y=35.3+$ $0.08x$ $r=0.19$	$Y=41.1+$ $0.16x$ $r=0.61$
						$-0.49x$ $r=-0.49$
						--

Source: ESE, 1981.

require only 30 percent of the time required by density methods to reach a 100-percent IS value. To reach a lesser IS value (80 percent), the cover methods require only 48 percent of the time commitment of density-based methods. In general, it appears that cover methods are more efficient for shrub sampling than are density methods.

274. The mean time required to adequately sample a site to achieve a species composition value identical to a census value (100-percent IS) would be at least four to six times as much as the time required to meet the 15-percent CAL for total density or cover. By using a lower standard of accuracy (80-percent IS), the level of effort can be reduced to as little as two to three times that required for the 15-percent CAL.

275. In general, the shrub-dominated transitional areas between uplands and marshes require the greatest sampling effort. Apparently, zones in which there is a transition of dominance from one stratum to another have a large, innate variability in data. Where there are areas with many individuals mixed with areas with no individuals, the variability will be high, and the sampling effort greater.

276. Shrub accuracy. Few prior studies have evaluated either efficiency or accuracy in shrub sampling methods. Stephenson and Buell (1965) evaluated the reproducibility of data from successive replications of the line-intercept method. They found this method to be suitable for mean values of each species in relatively simple communities and to have high reproducibility of data.

277. Oldemeyer and Regelin (1980) compared census values to the results of nine methods (three quadrat, four distance, and two distance-compensated for non-normal positioning) for three species. Their results showed substantial variation among results for each species for each method. In general, however, they found that non-compensated distance methods were inferior to quadrat

methods, angle-order, and corrected-point-distance methods. The quadrat and compensated distance methods were found to yield density values consistently within 25 percent of the true value.

278. Oldemeyer and Regelin (1980) found that the accuracy of quadrat methods was determined by the degree of aggregation and the clump size of each species. They felt that 5-m<sup>2</sup> quadrats were sufficient to overcome the aggregation effect in paper birch and willow. Smaller quadrats generally underestimated populations.

279. ESE's results in Louisiana indicate that even larger quadrats may be preferable. Total shrub density was better measured by 25-m<sup>2</sup> quadrats than by 16-m<sup>2</sup> quadrats. The belt transects, which consisted of 1-m<sup>2</sup> units, consistently overestimated density by up to 100 percent.

280. Lyon (1968) compared 12 quadrat and 6 non-quadrat methods for shrub sampling. He found that only square and rectangular quadrats and the wandering quarter method yielded density data accurate to within two standard errors of the mean at his level of effort. The point-quarter method also was precise in reducing variation among samples, but, like other plotless methods, it was not accurate. ESE data agree with both of these studies in that the point-quarter method consistently underestimated total density.

281. Figure 22 compares the calculated IV to that of census data. These data are expressed on the basis of a linear regression. Four methods (point-quarter, 5-m by 5-m regularly placed quadrats, 4-m by 4-m regularly placed quadrats, and visual estimate of canopy cover) consistently appeared to provide IV within 10 percent of true value. Three other methods (5-m by 5-m randomly placed quadrats, perpendicular belt transects, and line-intercept cover method) appeared to yield values within 20 percent of true value. The three remaining methods did not appear to provide adequate accuracy.

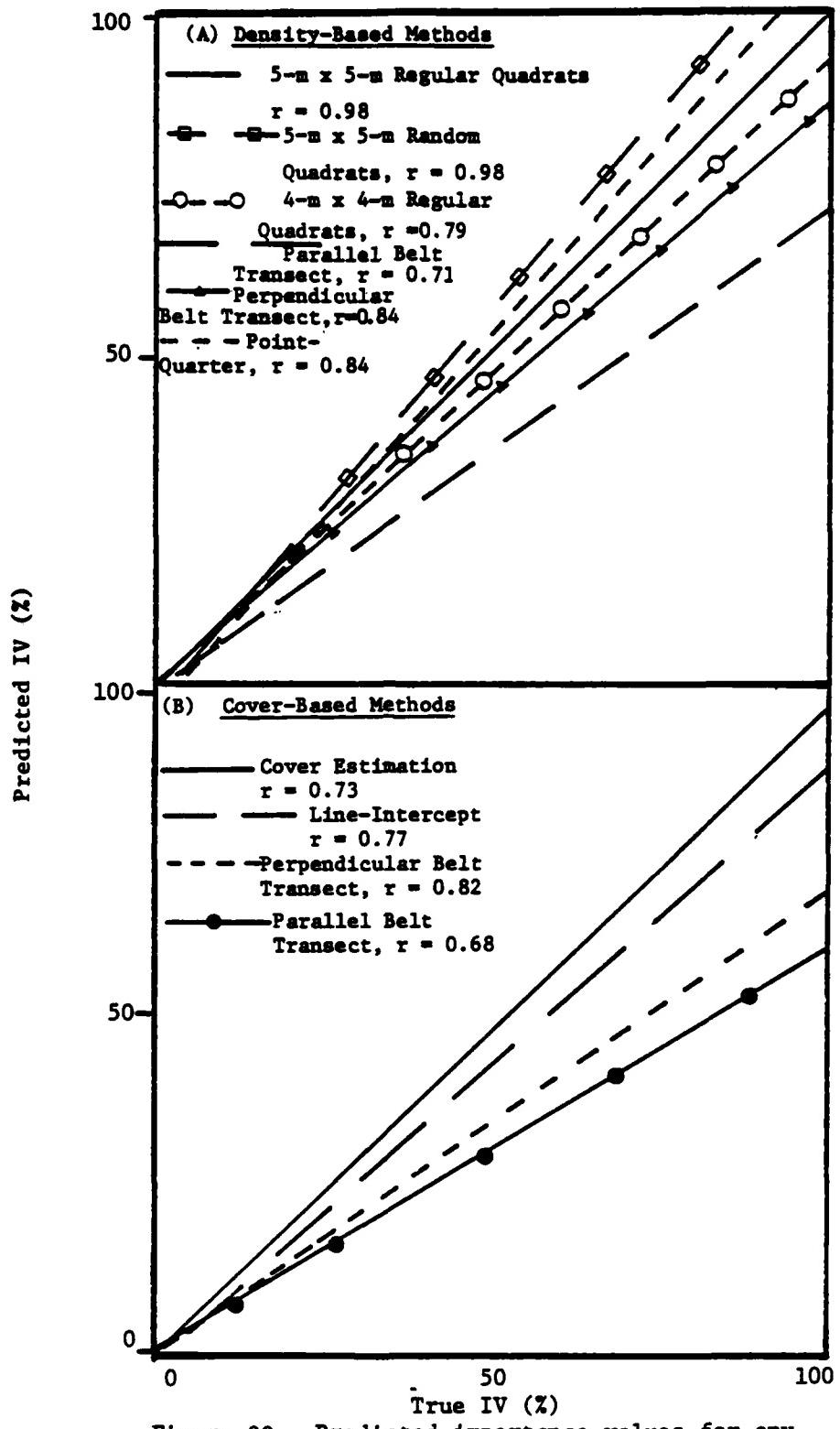


Figure 22. Predicted importance values for any shrub species compared to true importance value as determined from Site C census.

282.  $IS_{BC}$  values were less consistent, although most methods appear to have a linear relation to both total density and species number (Figures 23 and 24). However, the regressions indicate that at the 15-percent CAL level of sampling, none of the methods can be expected to produce an  $IS_{BC}$  value of over 80 percent if stands with over 15 species of shrubs or densities of under 3,000 shrubs/ha are sampled.

283. Oldemeyer and Regelin (1980) point out that while distance measures often are faster for studies of individual species, the quadrat methods will sample for all species simultaneously. Thus, for an equivalent level of effort, these methods provide greater and more usable data. Data from the Louisiana studies tend to support this conclusion.

284. Summary. Of the methods tested, it is recommended that one of two density-cover combinations be used in Louisiana transition zone species composition studies. One method is the use of 4-m by 4-m density quadrats with visual estimates of cover in each quadrat. The other method is the 1-m-wide perpendicular belt transect for density, using one edge of the belt for line-intercept cover measurements. When species composition determination is the objective of the study, the belt transects are recommended; when total density is the most important parameter, the quadrats are recommended.

#### Herbaceous sampling methods

285. Herbaceous efficiency. On the average, circular quadrats were found to be slightly more efficient than other shapes (see Figure 14), but the differences among shapes were slight, with less than a 15-percent difference in required sampling time between the least efficient and the most efficient shapes. Quadrat size, however, has a major impact on efficiency; the 0.125-m<sup>2</sup> (1.36-ft<sup>2</sup>) quadrats allow a 15- to 60-percent lower sampling effort than the next smaller size.

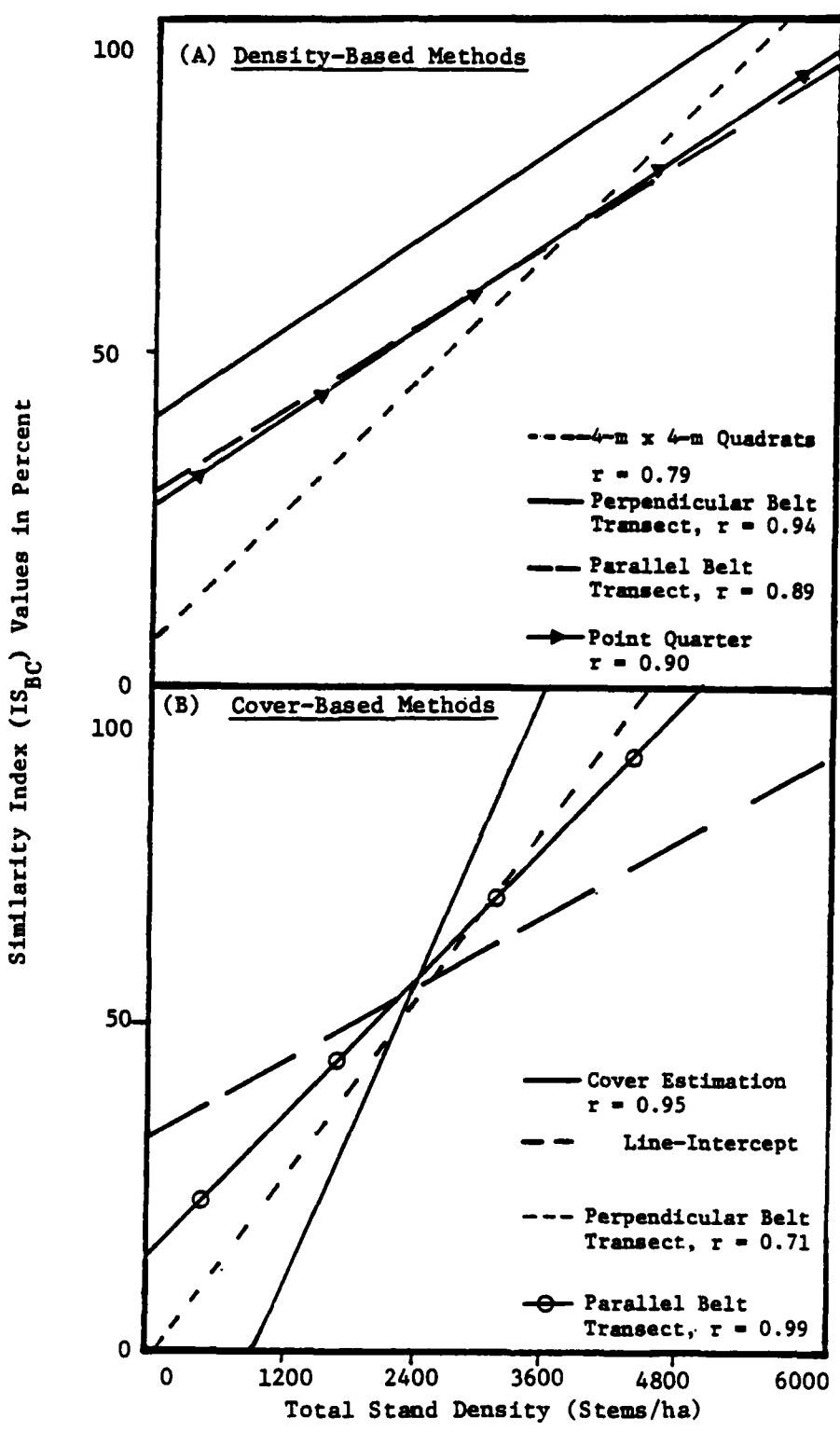


Figure 23. Relationship of similarity index ( $IS_{BC}$ ) of shrub sample data (compared to Site C census data) to total stand density.

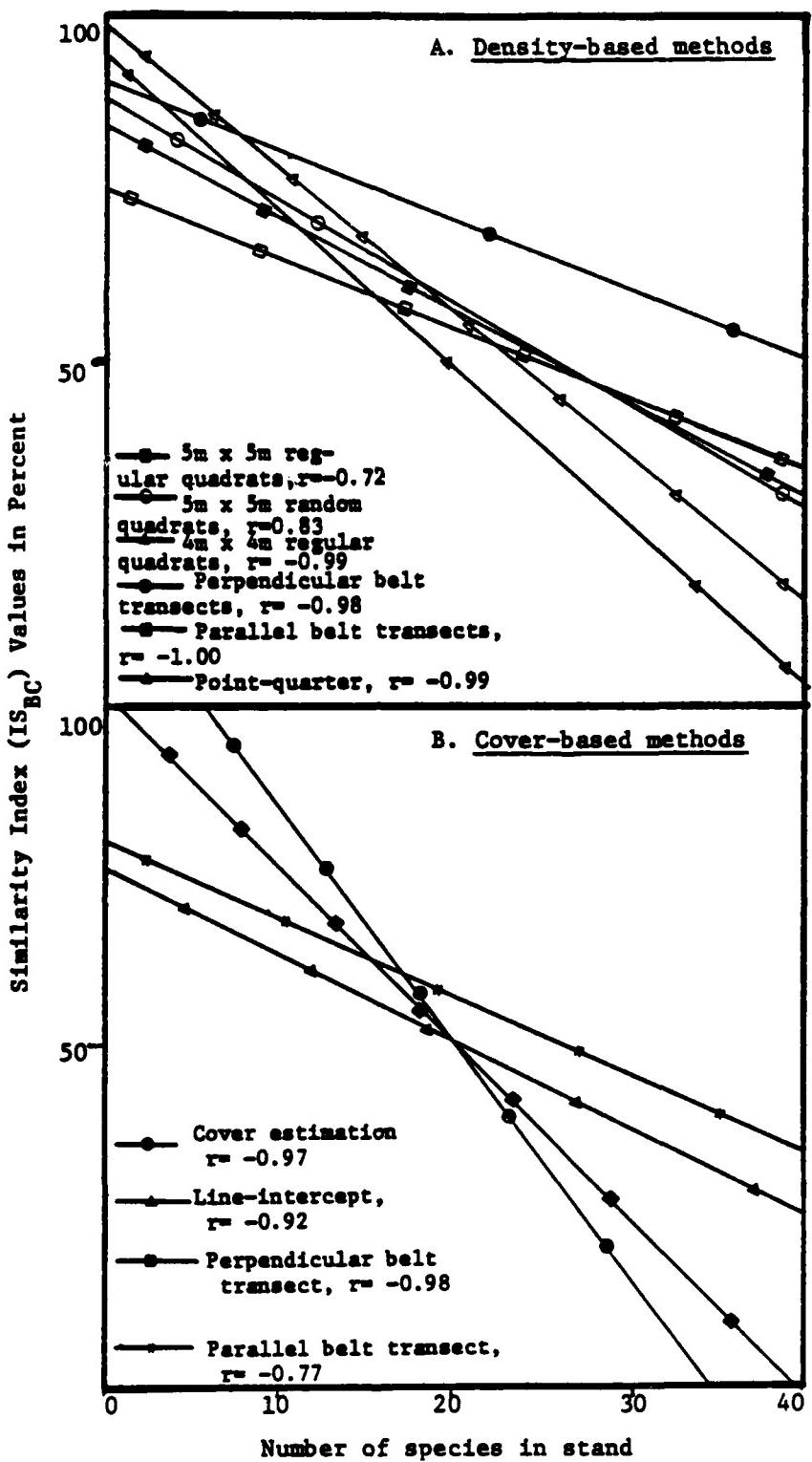


Figure 24. Relationship of similarity index ( $IS_{BC}$ ) of shrub sample data (compared to Site C census data) to number of shrub species found in stand.

286. Table 27 shows the amount of area determined to be the minimal sampling area necessary for different community types. For all of the quadrat and belt-transect methods, the minimal area is least in the herbaceous-dominated communities and greatest in the tree-dominated wetlands (swamps).

287. Such sampling areas are within the ranges reported in the few reported studies of adequacy of quadrat methods for herbs. Rice (1952) found that as few as nine  $0.1\text{-m}^2$  quadrats were sufficient for identifying species presence in prairies, but that several times as many quadrats would be needed for quantitative data. ESE data from Louisiana show that such a low number of quadrats may be sufficient for quantitative studies in a high-density, low-diversity system (i.e., salt marsh), but that in areas of minimal density (i.e., cypress swamp), as many as 200 such quadrats may be insufficient.

288. Wiegert (1962) sampled an old field with nested quadrats ranging in size from  $0.016\text{ m}^2$  to  $0.25\text{ m}^2$ . He found a quadrat size of  $0.188\text{ m}^2$  to be most efficient for forbs and total green material, while a  $0.047\text{-m}^2$  size was optimal for grasses. In all cases, the  $0.25\text{-m}^2$  size was less efficient than the  $0.188\text{-m}^2$  size. Wiegert felt that optimal quadrat size is dependent upon type of vegetation. Grasses were more randomly distributed than forbs, so smaller plots were effective. He found that forbs were aggregated with a mean clump size near  $0.047\text{ m}^2$ , so that quadrats larger than this clump size were necessary. It appears that quadrats as small as  $0.047\text{ m}^2$  may be suitable for sampling Louisiana salt marshes, but for general applications, the  $0.125\text{-m}^2$  or  $0.188\text{-m}^2$  sizes are better suited.

289. Figure 25 shows calculated relationships between the level of effort required for a 15-percent CAL and two vegetative parameters. It appears that the  $0.25\text{-m}^2$  quadrats consistently require about twice the sample area of  $0.125\text{-m}^2$  quadrats over all the possible conditions likely to be found in the Louisiana

Table 27  
Minimum Sampling Area ( $m^2$ ) Required to Attain a 15-Percent SEM for  
Mean Value as a Function of Quadrat Size for  
Each Major Physiognomic Type

Zone	Dominant Strata	Quadrat Size			
		<u>0.125-<math>m^2</math></u>	<u>0.250-<math>m^2</math></u>	<u>0.500-<math>m^2</math></u>	<u>1.000-<math>m^2</math></u>
Wetland	Herb	1.3-3.8	5.0-13.3	7.5-11.5	12.0-15.0
Transition	Shrub	1.5-12.5	6.5-20.0	10.5-24.0	40.0
Transition	Tree	2.8-11.5	10.0-35.0	11.5-24.0	12.0-26.0
Upland	Tree	2.8-11.5	10.0-35.0	11.5-24.0	12.0-26.0
Wetland	Tree	22.0	89.0	85.0	119.0

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Source: ESE, 1981.

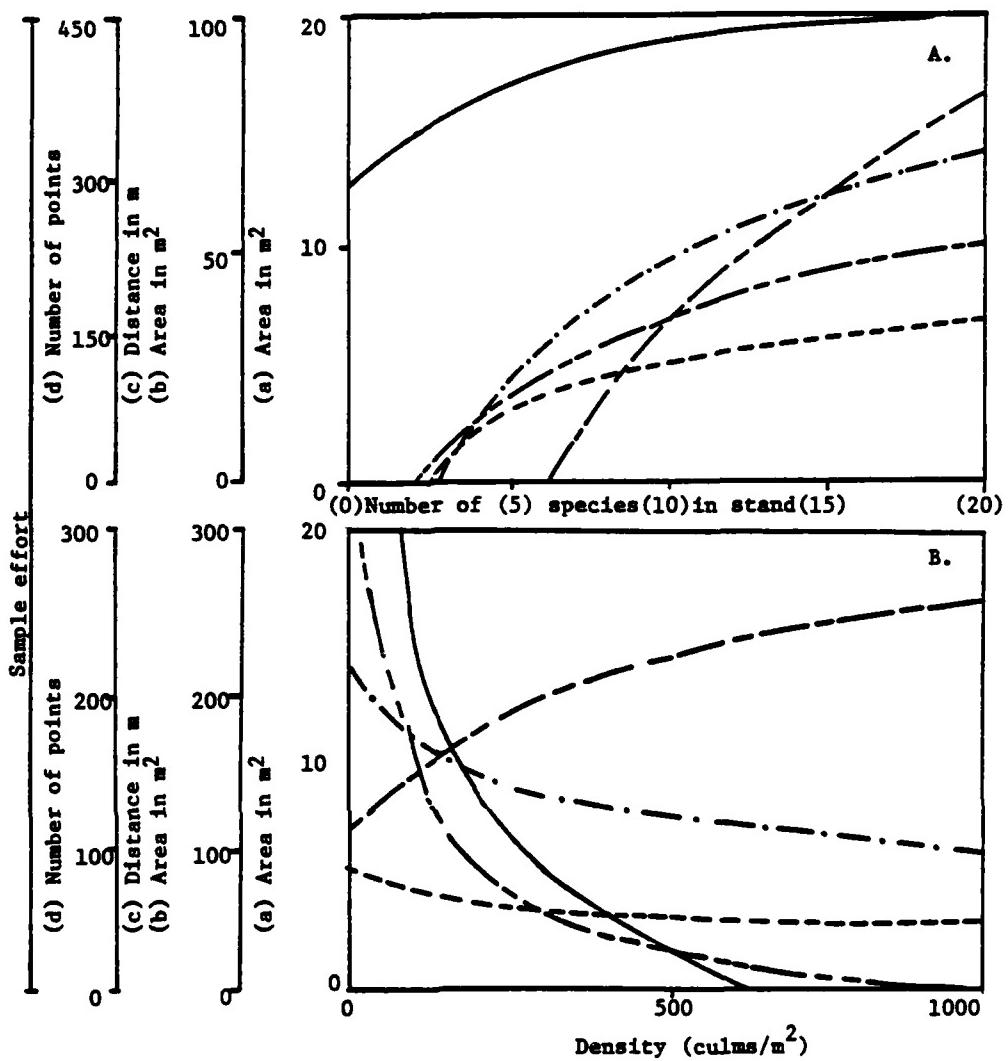


Figure 25. Total sampling effort required to sample herbaceous stratum with 15% SEM, predicted by best-fit regression analysis of data from Sites A and B in relation to species number (A) and stand density (B). Sample effort for quadrats and belt transects in m<sup>2</sup> (Scale A); for visual cover estimation in m (Scale B); for line-intercept in m (Scale C); and for point-intercept in number of points (scaled). Regression equations in Appendix Table B-9. Methods shown are:  
 0.125-m<sup>2</sup> belt transect (—)      Cover estimation (---)  
 0.250-m<sup>2</sup> quadrats (— —)      Point-intercept (- - -)  
 Line-intercept (— — —)

area. When translated to sample time, however, the difference in effort is reduced to a 15- to 60-percent difference.

290. The line-intercept modification and the visual cover estimation were found to be more efficient than any of the density-based methods. The levels of effort required for all of the cover-based methods appear to have a logarithmic relation to plant density and species number, but a linear relation to cover (not shown). Most methods require the least sampling effort when density and cover are high and species diversity is low. Until additional data are obtained, all of these relationships should be viewed as tentative. The correlation coefficients ( $r$ ) are consistently low (0.064 to 0.699), indicating that the variations are not explained entirely by these factors.

291. Canfield (1941) evaluated the line-intercept method on a bunchgrass-dominated rangeland, using 0.25-cm sampling intervals. He found that a minimum of 16 lines (242 m to 484 m) was needed for adequate results.

292. Whitman and Siggeirsson (1954), in comparing the line-intercept to two variations of the point-intercept method, found that at a specific level of effort, the line-intercept method had an SEM under 10 percent for total population and for each species. At the same level of effort, the all-contacts method yielded similar results for all but one species; the basal-contacts variation yielded a 10-percent level only for the three dominant species.

293. When levels for each individual species are considered, the line-intercept method is preferable to the point-intercept methods. Whitman and Siggeirsson (1954) found that 60.6 m of line-intercept, 400 all-contact points, or 600 basal-contact points were necessary to reach the 10-percent SEM level for total community cover.

294. ESE's results from Louisiana indicate that from 10 to 60 m of modified line-intercept or 50 to 800 all-contact points

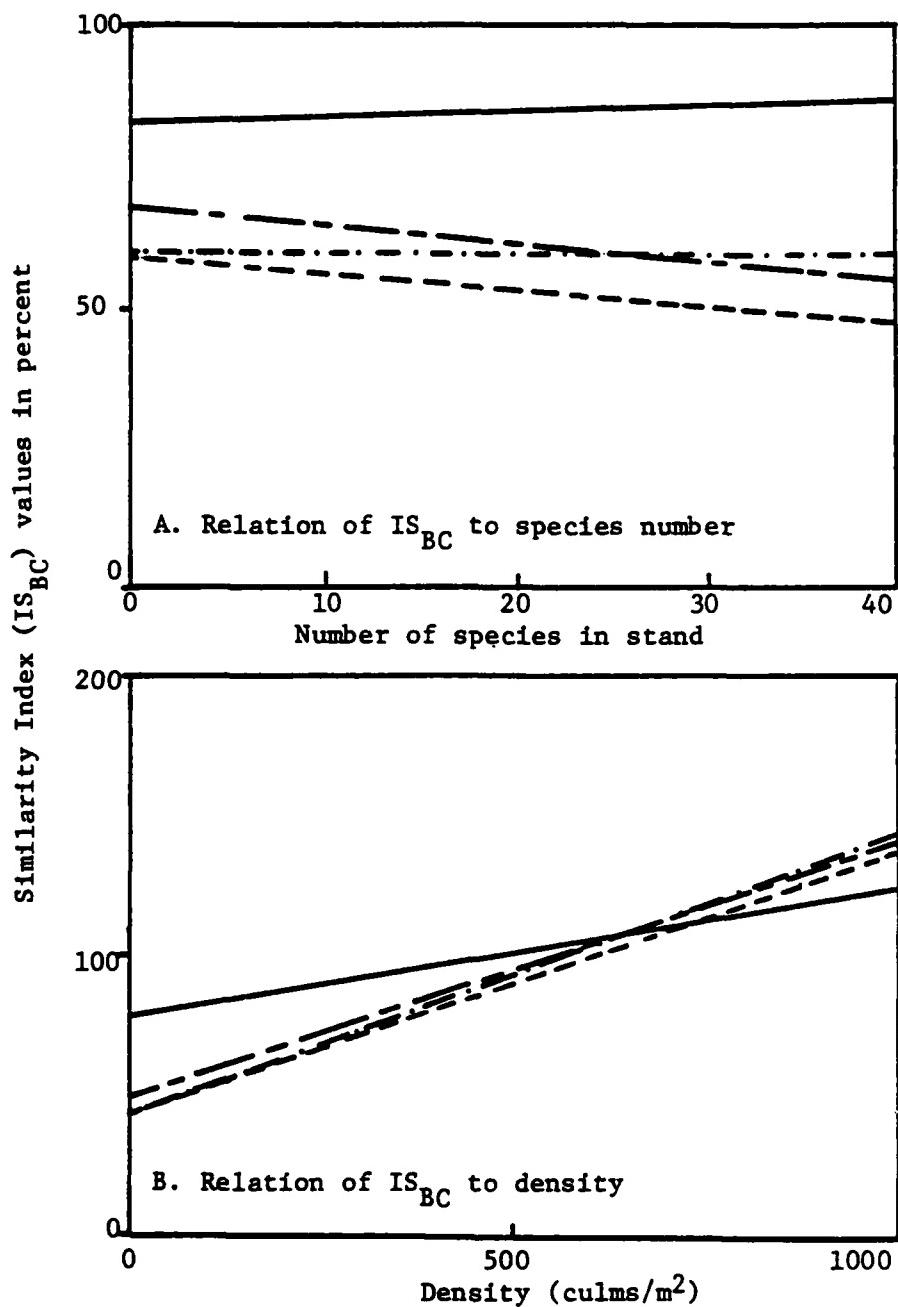
were adequate. The level of variation in ESE data is due to the varied nature of the different herb strata.

295. Herbaceous accuracy. Figures 26a and 26b illustrate the IS<sub>BC</sub> values for selected methods as functions of density and species number. Accuracy in determining species composition apparently has no significant relation to and is generally independent of species number. A qualitative IS would show a closer relation since it is dependent more upon the presence of minor species.

296. Both cover- and density-based methods show a weak but distinct direct linear relationship to increasing density ( $r = 0.54$  to  $0.79$ ). At the lowest densities, the  $0.250\text{-m}^2$  quadrats appear to be more accurate, but at the densities commonly found in marshes and most transitional areas the other methods are as accurate. No consistent relationships to total cover were found.

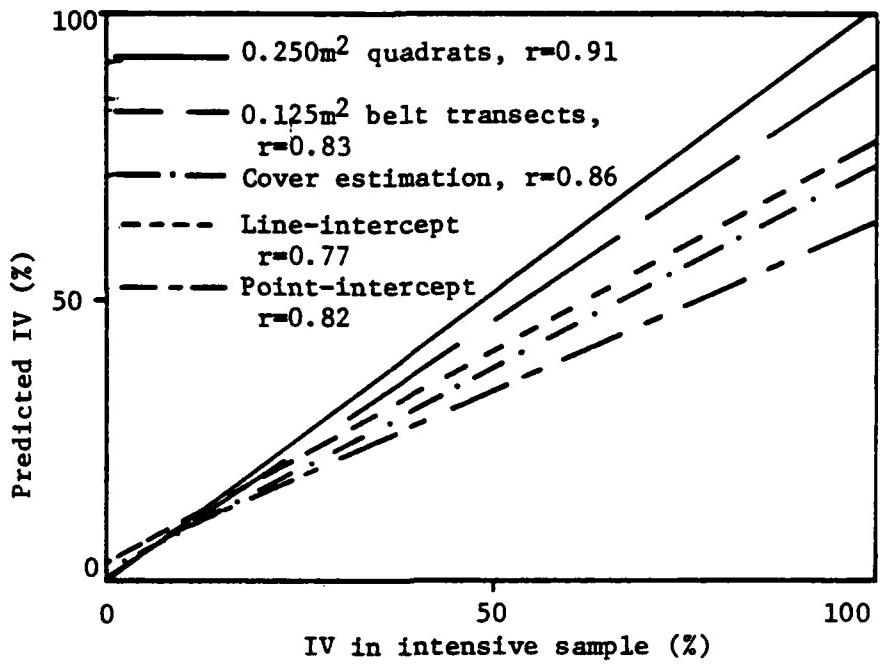
297. Figure 27 compares the predicted IV from each sampling method for any species to that found with intensive sampling. Quadrat methods yielded values within 10 percent of the true values with a high degree of correlation. However, the  $0.250\text{-m}^2$  quadrats formed a portion of the intensive sampling and thus are biased. Line-intercept and visual cover estimates gave an IV within 20 to 30 percent of true value.

298. Since line-intercept, visual cover estimate, and  $0.125\text{-m}^2$  belt transect data all were based on about one-half the level of effort of the  $0.250\text{-m}^2$  quadrats, an increase of no more than 50 percent in level of effort for these methods could yield equivalent accuracy while still requiring less effort than the quadrats. With such a 50-percent increase in effort, it is estimated that an SEM of 10 percent for total community population also would result.



**Figure 26.** Relationship of similarity index ( $IS_{BC}$ ) of herbaceous sample data (compared to intensive sample) to number of herbaceous species found in stand (A) and to stand density (B). Results based on data from Sites A, B, and C. Regression equations shown in Appendix Table B-10. Methods shown are:

0.250- $m^2$ quadrats (—)	Line-intercept (----)
0.125- $m^2$ quadrats (- - -)	Cover estimation (- · -)



**Figure 27.** Predicted importance value for any herbaceous species compared to Importance Values determined from intensive sampling efforts. Results from data from Sites A, B, and C. Regression equations in Appendix Table B-11.

299. Whitman and Siggeirsson (1954) found similar accuracy trends. They also found that the total cover as estimated by point-intercept methods was about 50 percent higher than that estimated by line-intercept. The basal-contact variation overestimated individual species populations by up to 100 percent.

300. For identifying the presence of species, Whitman and Siggeirsson found that the line-intercept method identified 89 percent of the 57 species in their sample area, while the all-contacts method identified 86 percent and the basal contacts only 39 percent. In the ESE study, visual cover estimates identified at least 60 percent of the species in each zone. All other methods identified as few as 40 percent of the species in at least one zone.

#### Summary

301. Overall, it is felt that for transition zone studies in Louisiana where identification of species presence/composition or total density/cover is important, the combination of  $0.125\text{-m}^2$  unit belt transects and the line-intercept modification represents the most efficient sampling method with suitable accuracy.

302. In areas where herbaceous vegetation is very sparse, as might be found along a gradient from permanently flooded swamp to upland forest, the use of belt transects with  $0.250\text{-m}^2$  units and a visual estimation of cover within units is more efficient and may be substituted.

## PART IV: PHASE II STUDY--FIELD VERIFICATION

### Introduction

303. At the conclusion of the Phase I sampling and analysis program, a set of sampling methods was selected as the best for sampling herb, shrub, and overstory layers on the basis of accuracy and efficiency in reducing variability. For each stratum, a method based on the cover parameter and a method based on the density parameter were selected. For the overstory stratum, a method for obtaining basal area data also was selected.

304. During the Phase II field verification process, the selected methods were used and evaluated at six additional study sites. These methods were then subjected to a variability evaluation and an accuracy evaluation similar to those made during Phase I. The first objective was to determine whether the levels of effort (number of samples) predicted to be adequate during Phase I would indeed be adequate and accurate for additional sites and community types representative of Louisiana wetlands.

305. A second objective of Phase II studies was the determination of the potential utility of these sampling methods for boundary delineation with transect-based studies. These studies, which delineate quantitative changes in vegetation along gradients, should therefore be useful in detecting wetland and transition zone boundaries.

### Description of Sites

306. The study sites for Phase II were chosen using the same criteria as for Phase I sites. The same types of difficulties were encountered; therefore, selection was less restrictive, particularly with respect to degree of disturbance.

307. Two sites each were selected for herb, shrub, and tree-dominated wetlands. One site of each type was chosen within Fontainebleau State Park for the purpose of representing coastal zone communities. The second site of each type was selected within Chicot State Park. Since Chicot State Park is located in the central highlands about 50 miles northwest of Baton Rouge, these sites represent communities within a different physiographic zone. All of the sites studied in Phase II were located in freshwater areas.

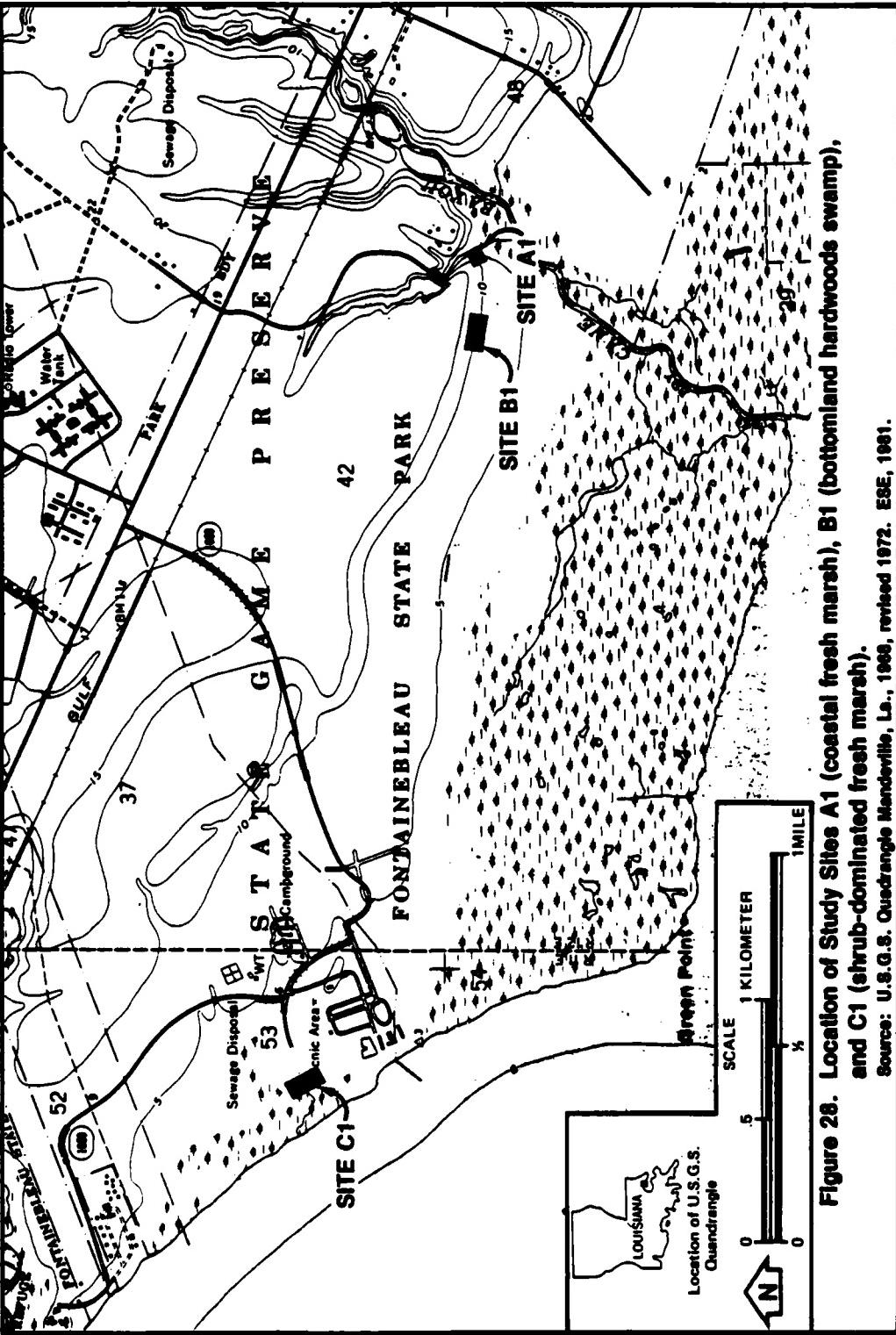
Site A1 (coastal fresh marsh)

308. Site A1 is a freshwater marsh community along the inner (upland) edge of the Louisiana coastal marshes. The site is located in Section 42, T8S, R12E at the eastern boundary of Fontainebleau State Park (Figure 28) on the west shore of Cane Bayou about 200 m (660 ft) south of the group camp. The study site consists of a 40-m by 30-m area centered along the transition zone.

309. Cane Bayou is a freshwater creek emptying into Lake Pontchartrain about 500 m (1,650 ft) downstream of Site A1. The brackish marsh on which Site A was located grades into intermediate marsh and then into fresh marsh near the mouth of the bayou.

310. This fresh marsh has a width of about 60 m (200 ft) and is similar to Penfound's (1952) "deep marsh" category. Giant cut-grass, smartweed (Polygonum hydropiperoides), and alligator-weed dominate the deeper zones, where water depths ranged from 0.3 to 0.7 m at the time of sampling.

311. The transition zone is abrupt and estimated to be little more than 5 m (16.5 ft) in width. E elevational differences of 0.3 to 0.7 m between the marsh edge and the upland have resulted in a steep slope of 20 to 45 percent. Vegetation of the transition zone consists of either true upland or wetland species, with few "intermediate" species.



**Figure 28. Location of Study Sites A1 (coastal fresh marsh), B1 (bottomland hardwoods swamp), and C1 (shrub-dominated fresh marsh).**

Source: U.S.G.S. Quadrangle Mandeville, La., 1966, revised 1972. ESE, 1981.

312. The upland forest zone of Site A1 is similar in species composition to Site A, although loblolly pine and live oak are not as well represented. The forest zone has been disturbed by grazing, resulting in sparse herb and shrub strata.

Site B1 (bottomland hardwoods swamp)

313. Site B1, in the eastern part of Fontainebleau State Park (Figure 28), also was situated within the forest community represented by the upland portions of Sites A and A1. During Phase I, this forest was considered to be an oak-pine-sweetgum upland community. However, the forest occupies very low land, and in places has characteristics more consistent with floodplain hardwood forests.

314. At Site B1, the shrub stratum is much less well-developed than at Site A. Park rangers have stated that this portion of the forest is prone to flooding every second or third year. Therefore, this site was chosen as a potential transition between marginal wetland and a true oak-pine upland forest. Since initial visual examination revealed few compositional distinctions between the upper and lower ends of this 100-m (330-ft) by 60-m (200-ft) site, it was determined to be a good test of the ability of quantitative sampling to distinguish among zones where the gradient of species dominance is slight.

315. Site B1 is situated along the slope between the 3.3-m (10-ft and 4.9-m (15-ft) contour levels. The slope in this transitional area is 5 to 20 percent; slopes of the "flats" above and below this zone are less than 5 percent.

316. Loblolly pine is the major tree species in all zones, with trunk diameters ranging from 38.4 cm (16 in) to 52.8 cm (22 in), and heights from 25 m (83 ft) to 30 m (100 ft). Sweetgum, southern red oak (Quercus falcata), and ironwood are common, with black gum, sweetbay (Magnolia virginiana), southern

magnolia (M. grandiflora), water oak, cow oak (Quercus michauxii), and hickories also present.

317. Throughout much of this site, the shrub and herb layers are sparse. Originally, the lack of such cover was ascribed to past grazing activity. However, quantitative sampling indicated that this cover was not evenly distributed as it would be due to grazing, but followed an elevational gradient.

318. Two grasses, Uniola laxa and Oplismenus setarius, in varying combinations, comprised the majority of relative importance of the herb strata in all zones, although a mean species richness of 18 species per zone occurred. Graminoid species and vines followed these two species in prominence. Vines also dominated the shrub strata. Grape (Vitis rotundifolia), poison ivy (Rhus radicans), Virginia creeper (Parthenocissus quinquefolia), American beautyberry (Callicarpa americana), and seedlings of abundant tree species were common.

#### Site C1 (shrub-dominated fresh marsh)

319. Site C1 represents a transition from a shrub-dominated (over 40 percent shrub cover) coastal fresh marsh to an oak-pine forest. Site C1 lies between Sites A and C on the north shore of Lake Pontchartrain (Section 53, T8S, R11E) in Fontainebleau State Park (Figure 28). Site C1, about 300 m (990 ft) west of the park's swimming pool, has a southwest exposure. It differs from Site A in that it is more fully separated from the lake's influence by a well-developed, stable sand berm about 0.5 m (1.7 ft) to 1.0 m (3.3 ft) above mean lake level. This berm restricts brackish water access to the marsh. Small drainage canals and ditches along the upper edge of the marsh carry fresh water from the park's sanitary sewer system to the marsh.

320. This combination of berm and freshwater flow augmentation has allowed a freshwater component of this marsh to develop and has allowed invasion by shrub species. At the time of

sampling in October, smartweed and alligatorweed were the dominant herbaceous species. However, during an early summer reconnaissance, pickerelweed, water hyacinth (Eichornia crassipes), and various arrowhead species were apparently dominant. Groundsel, wax myrtle, blue palm, and buttonbush comprise the shrub strata.

321. The upland zone is similar to the oak-pine forest of Site A, except that the ground appears to be lower and more moist. Ditches have affected the transition zone and reduced the shrub component. Water depths in the ditches and in the deeper parts of the marsh were less than 30 cm (1.0 ft) in October, but had been up to 75 cm (2.5 ft) in early summer.

Site A2 (shallow fresh marsh)

322. Site A2 was situated near the southwest edge of Chicot State Park where Choctaw Bayou enters the upper end of the lake (Figure 29). This site, in the southwest quarter of Section 29, R2E, T3S of Evangeline Parish, occupies a small hill protruding into the floodplain. About 2 m (7 ft) of elevational difference is present.

323. Lake Chicot is an 830-hectare (2,000-acre) manmade lake about 5 miles north of Ville Platte. The land in this region is rolling with bluffs and valleys rising up to 15 m (50 ft) above lake level. The many valleys have intermittent streams with floodplains up to 300 m (1,000 ft) in width.

324. Site A2 represents a shallow fresh marsh in an upland province. The floodplain at this location is dominated by a buttonbush shrub swamp. However, a deeper channel between the buttonbush zone and the upland supports a marsh dominated by smartweed, alligatorweed, and lizards tail. The site consists of a 30-m (100-ft) by 40-m (133-ft) site extending into this marsh zone of the wetland.

325. Water depths in the channel at the time of sampling (September) ranged from 15 cm (0.5 ft) to 30 cm (1 ft). The

transition zone contains such wetland tree species as red maple, sweetgum, and tupelo-gum, and a sparse herb and shrub cover.

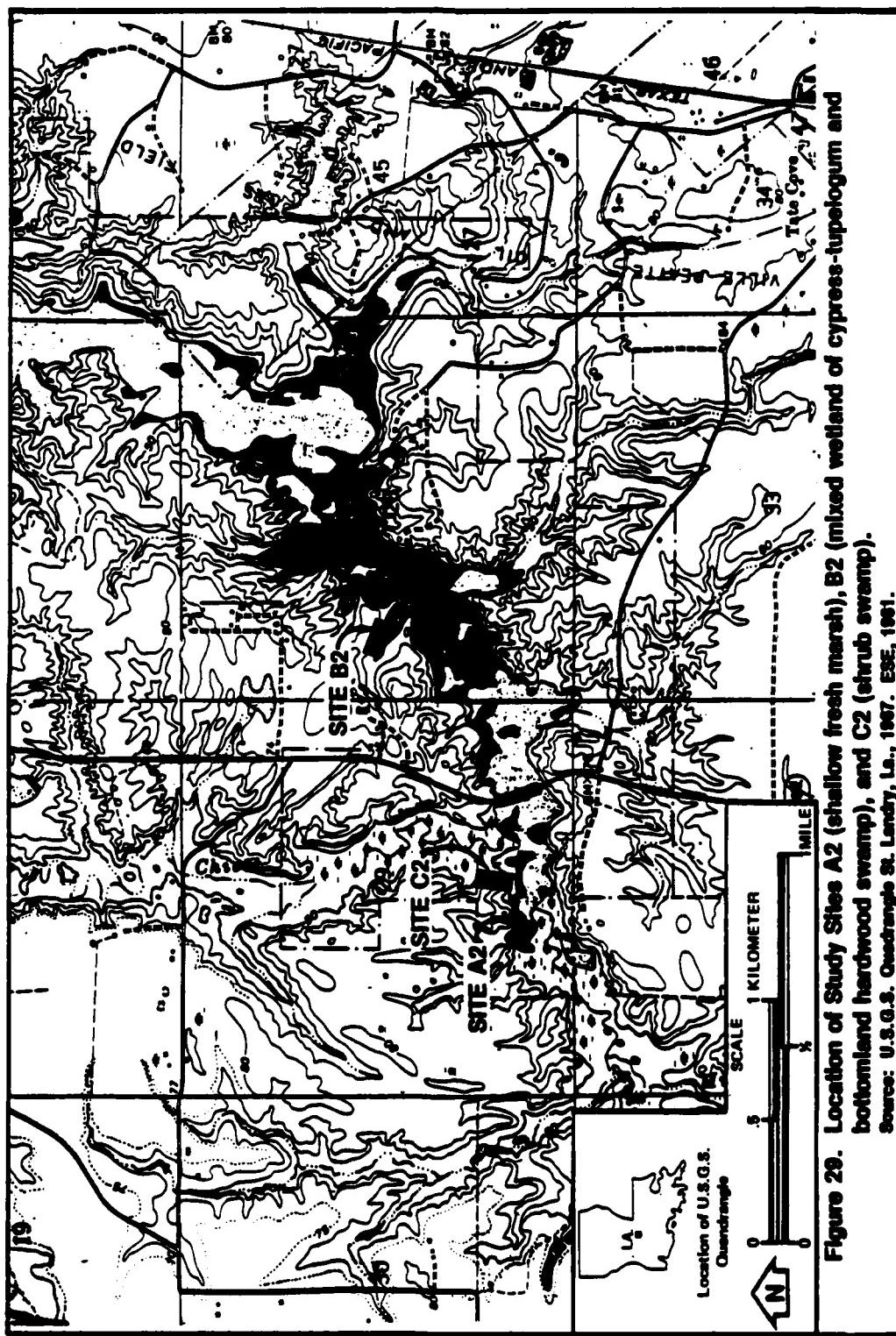
326. The upland portion of Site A2 has about a 5-percent slope. A rather open canopy layer contains ironwood and red maple in the lower areas, and southern red cedar (Juniperus silicicola), southern magnolia, and oaks in the upper zone. Due to the open canopy, the shrub and herb strata are well developed.

Site B2 (mixed wetland of cypress-tupelo-gum and bottomland hardwood swamp)

327. Site B2 is in Chicot State Park near the southern end of Lake Chicot (Section 28, R2E, T3S) about 350 m (1,155 ft) east of State Road 3042. It can be reached from the highway via two dirt roads about 500 m (1,650 ft) and 700 m (2,310 ft), respectively, north of the Lake Chicot bridge.

328. The vegetation of the region consists of upland hardwoods such as sweetgum, tulip poplar (Liriodendron tulipifera), dogwood (Cornus florida), winged elm (Ulmus alata), beech (Fagus grandifolia), various hickories and oaks, sugar maple (Acer saccharum), and ironwood (Carpinus caroliniana). This community is more typical of the northern part of Louisiana, and in parts of the park is in a near-virgin state. Wetland forest types consist of the cypress-tupelo-gum and bottomland hardwoods swamps similar to those of the coastal zone.

329. Site B2 was established on the south facing slope of one of these valleys on the lake (Figure 29). An ephemeral stream follows a well-defined channel through the 200-m (660-ft)-long valley. The valley has a maximum floor width of 50 m (165 ft). Just above the site, the stream becomes a series of poorly defined rivulets running down the head of the valley. Ground distance from the stream to the crest of the slope is about 70 m (230 ft) to 80 m (265 ft), with an elevational difference of 10 m (33 ft), giving a slope of about 15 percent.



330. The site extends 70 m (230 ft) from the stream channel to the crest of the slope. Because of the size of the area, overstory quadrat sampling was restricted to alternate 10-m-wide (33-ft) bands or zones running parallel to the side of the valley. The first zone sampled runs along the lower edge of the site.

331. The uppermost 20-m (66-ft) zone of the site consists of early secondary successional growth with most trees less than 3 to 5 m (10 to 16 ft) in height and 5 cm (2 in) in stem diameter. Spruce pine, winged elm, sweetgum, southern red oak, and blackberry are abundant.

332. The intermediate hillside is dominated by ironwood, sweetgum, water oak, southern red oak, and winged elm, with a canopy height of about 15 m (50 ft) to 20 m (66 ft). Stem diameters generally range from 12 cm (0.4 ft) to 24 cm (0.7 ft). Shrubs consist of saplings of the overstory species, with ironwood and water oak being most prevalent.

333. Two distinct community types occur in the lowest zone on the valley floor. The portion adjacent to and within the lake's floodplain consists of cypress-tupelo-gum swamp on saturated muck soils. The upper end of the valley, which may be flooded by the stream but not by the lake itself, supports a bottomland hardwoods community with red maple, ironwood, American elm (*Ulmus americana*), swamp cottonwood, and sweetgum. Thus, in addition to the vegetation/elevation gradient from the valley floor up the side of the valley, there is a second gradient running along the length of the valley, making a somewhat complex 2-dimensional gradient at this site.

#### Site C2 (shrub swamp)

334. Site C2 is on the western side of Bayou Chicot in the center of Section 29, R2E, T3S (Figure 29). The bayou at this point has a 200-m (660-ft)-wide floodplain dominated almost entirely by buttonbush. These shrubs are large, with heights of

3 m (10 ft) to 4 m (13 ft), and have dense coverage. Deep, soft peat soils were covered by water up to 30 cm (1 ft) in depth at the time of sampling.

335. The lower transitional zone consists of a low bar separated from the shore by a backwater channel about 5 m (15 ft) to 10 m (33 ft) wide, with water depths of about 30 cm (1 ft). Both bar and channel have clay soils. Water marks on the large black gum, red maple, and black willow trees indicated that water levels had been 1.08 m (45 in) higher in the spring.

336. The other side of the channel is characterized by a flat (less than 5 percent slope) zone about 20 m (66 ft) wide which would be flooded at high water. This zone grades into an upland zone which has about a 15-percent slope and is situated above the high water line. Both the level upper transitional zone and the sloping upland have soils consisting of clay loams with well-developed litter and A-horizons. Red maple, with some black gum, dominates the level transitional zone, while the slope is dominated by ironwood, sweetgum, winged elm, and cow oak.

#### Phase II--Field Methods

337. As a result of the Phase I field evaluations, best methods were selected for further verification in Phase II. The following methods were subjected to Phase II field verification:

- a. Overstory--100-m<sup>2</sup> circular quadrat for density determination combined with Bitterlich variable radius method for dominance (basal area) determination; cover determined either by line-intercept or by cover estimation within the quadrats.
- b. Shrub--One-meter-wide (1-m<sup>2</sup> units) perpendicular belt transect for density determination, combined with line-intercept method for cover determination.
- c. Herb--One-quarter meter wide (0.125-m<sup>2</sup> units) perpendicular belt transect for density determination, combined with line-intercept method for cover determination.

338. The selected Phase II methods were used in transect fashion; that is, the sampling units were arranged linearly along transect lines extending from the baseline (wetland zone) of the sampling site to the upper end (upland zone) of the site. The line-intercept and herbaceous and shrub strata belt transect methods consisted of contiguous units along this line at all sites.

339. The overstory quadrat and variable radius methods were used with contiguous units at five of the six sites. Contiguous units for the 100-m<sup>2</sup> circular quadrats and variable radius sampling points are defined here to mean that one quadrat or point was used in each 10-m (33-ft)-wide zone, such that the centers of each quadrat were 10 m (33 ft) apart. Since these quadrats have a diameter of 11.29 m (37.2 ft), these quadrats thus have a maximum overlap of 0.64 m or approximately 0.6m<sup>2</sup> (6.5 ft<sup>2</sup>) with each adjacent quadrat.

340. Trees were also censused and mapped in each study site. Analysis of these maps showed that the occurrence of trees within the overlap areas of the quadrats was very rare; therefore, the chance of counting a tree more than once is low. The method was judged to approximate the characteristics of completely independent quadrats sufficiently to use the statistical methods for independent quadrats without introducing significant error into the results.

341. In one instance (Site B2), the overstory method was varied to allow for more efficient sampling over a site with a broader wetland to upland gradient. In this case, the quadrat and variable radius samples were centered at 20-m (66-ft) intervals, so that every second 10-m (33-ft) zone was sampled instead of every zone.

342. All sampling methods were identical to those used in Phase I. For the cover methods, a 100-m (330-ft) fiberglass

measuring tape was laid along the ground surface. This tape formed the baseline for the line-intercept measurements. It also formed one side of the corresponding belt transect. This arrangement allows maximum efficiency, while yielding comparable results for the cover and density parameters. All transects were established using compass lines. Depending upon site characteristics, transects were laid out in either a regular or a stratified manner.

343. Phase II sites were selected to represent the range of community characteristics expected in Louisiana. In particular, the sites represent variation in density and cover values for each stratum, and they contain transition zones ranging from abrupt, well-defined edges less than 10 m (33 ft) in width to wide (40 m or 132 ft) gradual transitions.

#### Phase II Methods--Selection of Analysis Parameters

##### Variability and efficiency evaluation

344. Data were analyzed in a fashion similar to that for Phase I for calculation of SEM, CAL, and minimum sample size, as well as for accuracy. However, time was not considered a factor in Phase II sampling, other than on a general basis. All adequacy determinations are expressed on a sample number or area basis only.

##### Delineation parameters and criteria

345. In order to evaluate the relevancy of the resulting data in describing and delineating wetland and transition zones, data were evaluated for each 10-m-wide (33-ft) band corresponding to a row of 10-m by 10-m quadrats arranged parallel to the baseline of the study site. For the purposes of the Phase II evaluations, each of these bands was treated as a separate unit or "sampling zone" and treated as a unit along a transect. For each

site, the sampling zones were numbered consecutively beginning at the lowest edge of the site adjacent to the baseline. The term "sampling zones" in this report is distinct from the terms "zones" or "vegetative zones" used to define vegetation trends.

Development of a method for delineating transition zones requires consideration of three aspects of the method:

- a. Ranking sequence (order or sequence in which sampling zones are compared),
- b. Parameters (those vegetative characteristics of the data base that can be evaluated), and
- c. Criteria (set standards for parameters on which delineation decisions can be made).

346. Ranking sequence. Ranking sequence refers to the manner in which sampling zones are ranked or compared to one another. Comparisons among sampling zones were made in two different ways or sequences. The first comparison was among sampling zones along the transect gradient within each site. By this method, each sampling zone within a site was compared directly either to an adjacent sampling zone or to the sampling zone at one of the endpoints of the transect. All determinations made in this manner are dependent solely on data from within a single site, are site-specific, and are independent of results or interpretations from other sites.

347. The second ranking sequence method uses results from all sampling zones in the data base simultaneously to rank sampling zones along a wetland to upland gradient. Consequently, rankings within a site are not independent of those of other sites.

348. This method is based upon the vegetational Continuum Index (CI) concept of Curtis and McIntosh (1951) and Brown and Curtis (1952). Each zone (stand, quadrat, etc. as appropriate) is ranked on the basis of its relative position along a continuum or gradient, which in turn is based upon vegetative response to an environmental condition. The CI needs two parameters for

construction: the first is known as a Species Adaptation Number (SAN). The adaptation number concept was developed originally by Curtis and McIntosh (1951). Because they were using a continuum based upon successional relationships within a single forest association, they introduced the number as a "Climax Adaptation Number" (CAN). However, the concept can be used to rank species along any gradient such as the wetland-upland gradient of this study. SAN numbers are estimated measures of a species' ability to compete successfully under a set of environmental conditions.

349. SAN numbers for all species found during Phase I and Phase II sampling were determined on scales ranging from 0 to 10, with a value of 10 representing the highest degree of adaptation. Derivation of various SAN numbers is discussed later.

350. The second component of the CI is Importance Value (IV). For each sampling zone, the SAN of each species was multiplied by its IV, and the resulting values summed to give the CI [ $CI = \sum (IV \times SAN)$ ]. The value of any parameter in a sampling zone can be correlated to the CI, and its behavior over the wetland-to-upland gradient observed.

351. Parameters. Two groups of parameters were evaluated during this study. The first group included parameters of the community as a whole, for which information about dominance and species identification was not required. Use of these parameters for delineation would require a low level of field sampling effort because data requirements include only the number of species per zone and the total density or cover. This group of "community-based" parameters, derived directly from the raw data base, included:

- a. Total density,
- b. Total cover,
- c. Total basal area, and
- d. Species richness (the number of species found in a zone).

352. The second group of parameters may be considered to be "species-based" parameters. These parameters differ from the community-based group in that each requires a second-level step in reducing raw data to the form used in delineation. These groups also differ in that each is dependent upon knowledge of which species is present and/or the relative abundance of these species.

The species-based parameters are:

- a. Species diversity ( $H'$ )--calculated using the Lloyd et al. (1968) machine formula for the Shannon-Weaver function (Shannon and Weaver, 1949).
- b. Quantitative similarity index--uses the Bray-Curtis index ( $IS_{BC}$ ) [Formula (6) in Part II] based upon IV in each zone (Appendix Tables C-1 through C-6).
- c. Qualitative similarity index--uses Sorenson's index ( $IS_g$ ) [Formula (7) in Part II] based on presence of species in each zone.
- d. Indicator species groups--based on total IV of all species within indicator groups.
- e. Continuum index--ranking of all sampling zones based on Continuum index (CI) values.
- f. Indicator species--individual species distributions over the CI used as indicator of sampling zone location.

353. The indicator species groups, CI values, and indicator species parameters are based on SAN values. Four methods for determining these SAN and VIV values were tested. All methods of calculating SAN values are based upon the average position or range of occurrence of each species along the gradients or transects from wetland to upland. Each of the values is a measure of the relative distance in which each species would be expected to occur on a transect. All values are similar in this respect, but each is based on a slightly different response. For example, the  $SAN_w$  value is a measure of how close to the wetland a species may be expected to occur on a gradient;  $SAN_u$  value is a measure of how close to the upland extreme of a transect a

species may occur. The SAN<sub>c</sub> and VIV (or SAN<sub>v</sub>) values are based on a combined response to both extremes, not only on how close to the extremes each species occurs, but also how widely it is distributed between these extremes.

354. The first method was based on species tolerance to aggregate wetland environmental conditions, which is assumed to be directly correlated with the lowest sampling unit or sampling zone in which a species is found in a site. Computation of the SAN values for wetlands (SAN<sub>w</sub>) is shown in Table 28. For all of the determinations in this report, the sampling unit was defined as a 10-m-wide band or zone along the transects. Other means of defining units can be used; for instance, the distance in meters from the baseline could be used, if desired.

355. The number of the unit is its sequential order (1, 2, 3, 4, etc.) from the baseline. For example, in a transect containing four sampling zones, the lowest sampling zone would be designated Number 1 and the highest sampling zone Number 4 for the SAN<sub>w</sub> calculations. The number sequence runs in the reverse order for the SAN<sub>u</sub> calculations. The uppermost zone would be designated as Number 1 and the lowest zone a Number 4. A species found only in the lowest zone would have a SAN<sub>w</sub> value of 10.00 (1/1 · 10); one found only in the fourth zone would have a SAN<sub>w</sub> value of 2.5 (1/4 · 10). SAN<sub>w</sub> values were calculated for all species found in each of the nine Phase I and Phase II sites; the average values are shown in Appendix C.

356. The second variation of SAN values was based on the degree of tolerance to upland environmental conditions. Computation of this value SAN<sub>u</sub>, is shown in Table 28. Species with high SAN<sub>u</sub> values have high tolerances to upland conditions.

357. The relationship between wetland and upland tolerances also was considered as a parameter. Species with high wetland tolerances (SAN<sub>w</sub>) and low upland tolerances (SAN<sub>u</sub>) are restricted to wetland conditions. Species with high tolerance to both

Table 28  
Computation of Parameters Used to Rank Zones

<u>Parameter</u>	<u>Computation</u>
Wetland species adaptation number	$SAN_w = (\text{number of lowest sampling unit in which species occurred})^{-1} \times 10$
Upland species adaptation number	$SAN_u = (\text{number of highest occurring sampling unit in which species occurred})^{-1} \times 10$
Combined species adaptation number	$SAN_c = \frac{SAN_w}{SAN_u}$
Vegetational indicator value	$VIV = \text{raw score} \cdot X \cdot S$ $= (\text{occurrences in wetland units-occurrences in upland units}) \cdot X \cdot S$  $\text{where } X = (1 - \text{lowest raw score})$ $\text{and } S \text{ is a variable adjusting VIV values to a scale of 1 to 10.}$
Qualitative continuum index based on wetlands SAN values	$CI_{w-ql} = \frac{\sum SAN_w}{N}$
Quantitative continuum index based on wetland SAN values	$CI_{w-qn} = \sum (SAN_w \cdot IV)$
Qualitative continuum index based on upland SAN values	$CI_{u-ql} = \frac{\sum SAN_u}{N}$
Quantitative continuum index based on upland SAN values	$CI_{u-qn} = \sum (SAN_u \cdot IV)$
Qualitative continuum index based on combined SAN values	$CI_{c-ql} = \frac{\sum SAN_u}{N}$

(Continued)

Table 28 (Concluded)

Parameter	Computation
Quantitative continuum index based on combined SAN values	$CI_{c-qn} = \sum (SAN_c \cdot IV)$
Qualitative continuum index based on VIV	$CI_{v-ql} = \frac{\sum VIV}{N}$
Quantitative continuum index based on VIV	$CI_{v-qn} = \sum (VIV \cdot IV)$

Sources: VIV--Minore and Carkin, 1978.  
All other methods--ESE, Inc. 1981.

conditions are wide-ranging, and species with low wetland tolerance and high upland tolerance are restricted to upland conditions. The ratio of  $SAN_w$  to  $SAN_u$  is useful in distinguishing those species which are restricted to either wetland or upland conditions from those species which are transitional or widely tolerant species.

358. A species found only in the lowest sampling zone of the above example would have a  $SAN_w$  value of 10 and a  $SAN_u$  value of 2.5, representing a high tolerance to wetland conditions and a low tolerance to upland conditions. The  $SAN_c$  value is the ratio of the two; in this case 10/2.5 or 4. Conversely, the species restricted to the most upland zone would have a value of 2.5/10 = 0.25. The effect of using the  $SAN_c$  is to increase the relative difference of response of these two units ( $10 = 4 \times 2.5$  on the  $SAN_w$  and  $SAN_u$  scales, while  $4 = 16 \times 0.25$  on the  $SAN_c$  scale).

359. Two other species may be considered in this example, one of which occurs only in an intermediate sampling zone (third from the lowest). With a  $SAN_w$  value of 3.3 (1/3·10) and a  $SAN_u$  value of 5.0 (1/2·10), it is intermediate between the first two species. It has a  $SAN_c$  value of 0.66 (3.3/5). A fourth species which may occur in all four sampling zones would have values of 10 for both  $SAN_w$  and  $SAN_u$ , resulting in a  $SAN_c$  value of 1.00. The  $SAN_c$  values of 4.00, 1.00, 0.66, and 0.33 thus indicate the relative positions of tolerance of the four species along a wetland-to-upland gradient.

360. Numerous variations on this ranking or adaptation number concept have been reported, among them "comparative frequency" (Warner and Harper, 1972) and "vegetation indicator value" (Minore and Carkin, 1978). These methods rank or array species on the basis of frequency of occurrence in sampling units at each extreme of an environmental gradient. Vegetation indicator value (VIV or  $SAN_v$ ) was computed by first counting

the number of times a species occurred in subjectively defined upland zones and in wetland zones. The number of upland occurrences was subtracted from the number of wetland occurrences. When all differences were obtained, the species with greater upland tolerances had negative numbers. A value sufficient to raise the most negative number to +1 was then added to all values. For instance, if raw values of 5, 3, 0, -1, -4 were found, a value of 5 would then be added to all values to transform them to the positive number set (10, 8, 5, 4, 1). The highest number was then assigned an indicator value of 10, and the others were scaled proportionately to lie in the range of 0 to 10, in order to be equivalent to the SAN scale.

361. Criteria. All parameters were evaluated to see if patterns or gradients among sampling zones of each site were present, as indicated by the slope of graphed data. Various criteria were evaluated to determine if objective criteria limits could be established which consistently delineated boundaries at all sites.

362. An attempt has been made to limit the analyses to methods which are straightforward and readily understandable without the use of statistics or computer-enhanced data manipulations. Priority has been given to techniques which can be easily presented and interpreted as 2-dimensional graphic displays, and to establishing a given set of criteria and definitions which can be applied directly to any site in the region. Graphic delineation techniques were based on one of the two ranking sequences. Two basic methods of establishing criteria were used.

363. The ratio method made use of the ratio or relationship of two parameters. Several parameters could be compared to values found at one or the other endpoint of the transect. For example, a graph of IS values compared to the wetland endpoint of a transect would decrease approaching the upland endpoint, whereas IS values compared to the upland endpoint would increase and peak

at the upland endpoint. The two lines would cross at some intermediate point where a 1:1 ratio occurs. Similarity values ( $IS_{BC}$  and  $IS_g$ ) and species indicator groups ( $\Sigma SAN \cdot IV$ ) were evaluated using criteria based on wetland:upland relation ratios.

364. The second group of criteria consisted of threshold values. Using this type of criteria, data for each zone were independent of endpoint sampling zone values. Threshold criteria were defined as specified percentages of a maximum or minimum value (relative value data) or as absolute numbers, as applicable. All parameters were evaluated in terms of threshold criteria.

365. Threshold levels are set by the observer, and the initial definition is largely subjective. When possible, the most objective means possible should be used. For example, it was concluded in Phase I that an  $IS_{BC}$  level of 80 percent or above generally indicates that a sample value represents the same population as a census value; therefore, a basis exists for assuming that values below 80 percent probably indicate substantial deviation. Thus, an 80-percent  $IS_{BC}$  level may form a reasonable threshold value for assumption that one zone is sufficiently different from another zone to be considered a separate community (i.e., transition versus wetland).

366. Establishment of thresholds is an iterative procedure. As a first step, a subjective interpretation must be made of the nature of each zone, i.e., whether it is wetland, transition, or upland. Thresholds are then set, and the resultant delineations compared to the previously defined zones. A best-fit approach is used to correctly identify as many zones as possible. At this point, thresholds may be redefined and the process may be repeated. This process continues until maximum refinement occurs. An 80-percent threshold value was defined initially for similarity indices.

367. Species indicator groups were defined on the basis of the SAN<sub>C</sub> values. Figure 30 shows a plot of SAN<sub>C</sub> values for overstory species. The relative location of each species along a wetland tolerance gradient is shown by the vertical distance (SAN<sub>W</sub> axis), and the relative tolerance to upland conditions along the horizontal axis (SAN<sub>U</sub>). Each species point is based on the ratio of these values and represents the SAN<sub>C</sub> location of each species.

368. Shown by the diagonal lines are the ranges of values corresponding to values less than 0.5 (upland), 0.5 to 2.0 (transitional), and more than 2.0 (wetland). Such values appeared to best segregate species felt to be obligative wetland and upland species. It should be noted that these values are set arbitrarily. Species appear to be distributed evenly and randomly along the gradients, with little distinct aggregation. As a result of this grouping based on SAN<sub>C</sub> values, the wetland group of trees was defined as having 15 species, the upland group 17 species, and the transition group 27 species.

369. All overstory indicator groups were then defined as having 15 wetland species, 27 transitional species, and 17 upland species. Species composition in each group varied because for each parameter (SAN<sub>W</sub>, SAN<sub>U</sub>, SAN<sub>C</sub>, VIV), the groups were selected on the basis of the ranking within that group. The 15 "most wetland" species on the SAN<sub>W</sub> scale did not, for instance, correspond to those on the VIV scale. This procedure allowed comparison of several different species groupings.

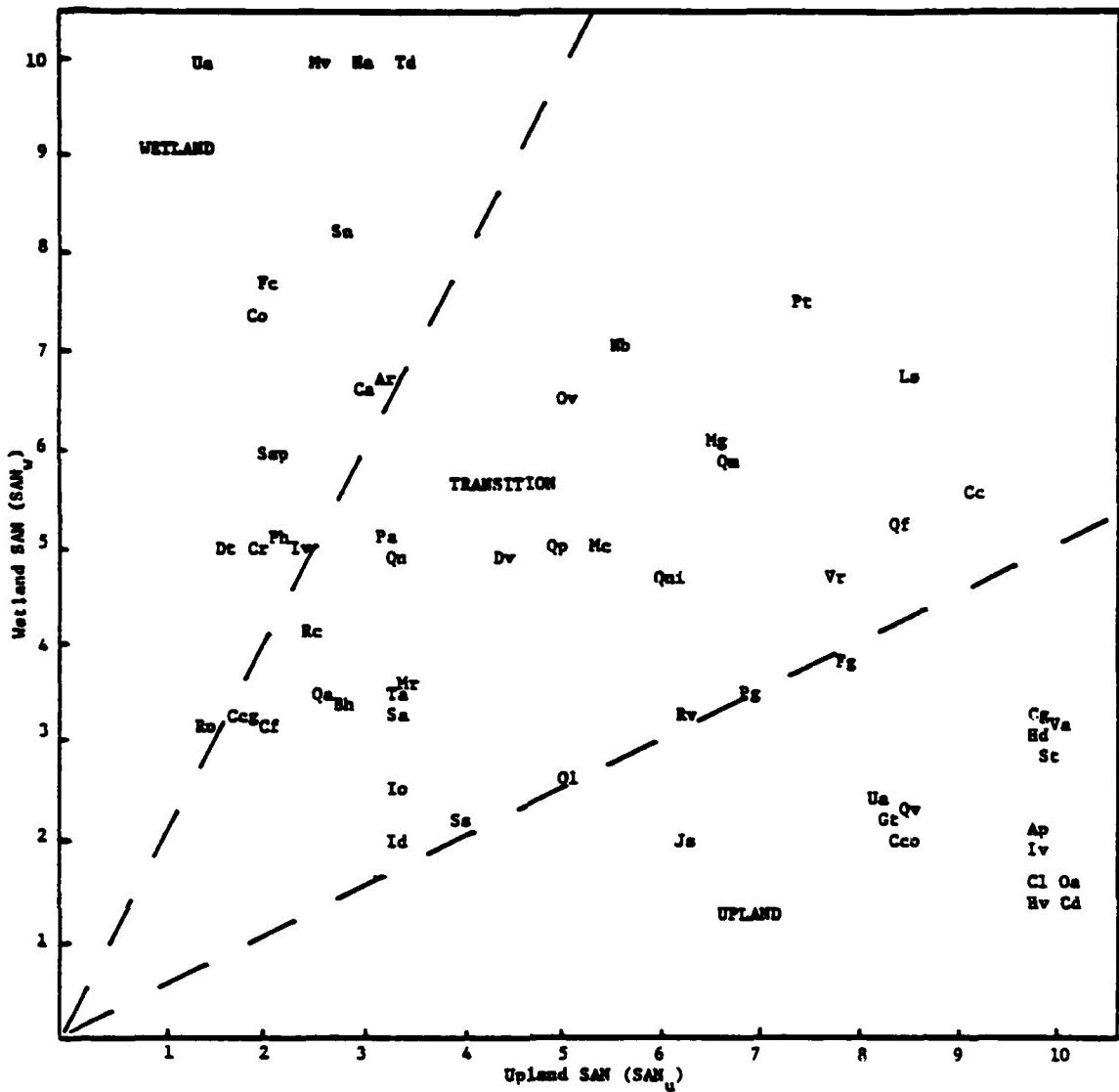


Figure 30. Ordination of overstory species on wetland ( $SAN_w$ ) and upland ( $SAN_u$ ) gradient axes. Points shown represent the relative  $SAN_w/SAN_u$  values ( $SAN_c$ ). Species are identified by first letters of scientific name. Diagonal lines represent arbitrary boundaries between wetland (upper), transition (center), and upland species. Boundary lines represent 2.00  $SAN_c$  (upper) and 0.50  $SAN_c$  (lower) values. Values are for each 10-m-wide zone starting from the lower end (Zone 1) of the sampling site.

PART V: PHASE II STUDY--RESULTS

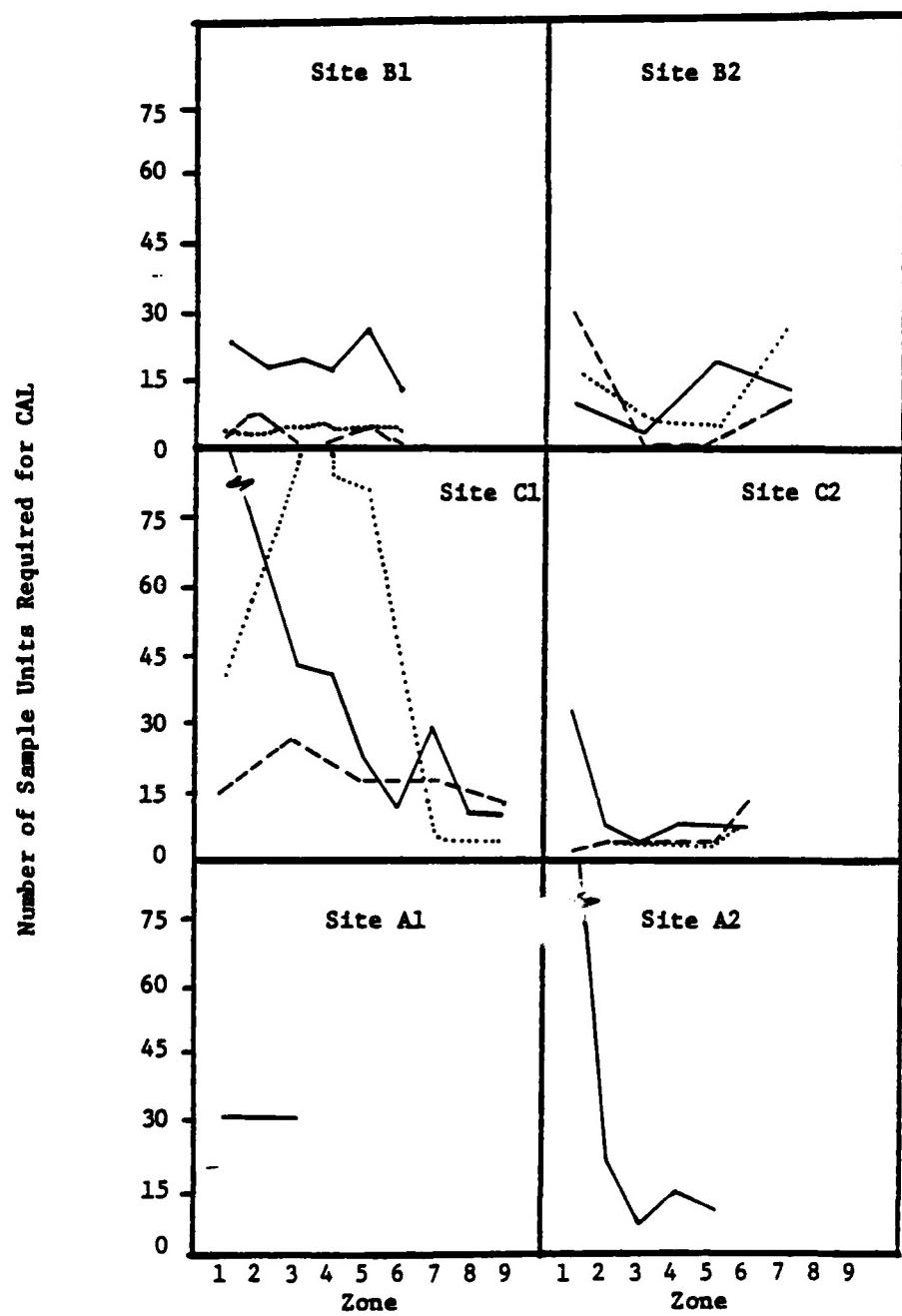
Sampling Efficiency

370. For each sampling zone, the 15-percent Constant Adequacy Level (CAL) was obtained either directly or was calculated using Formula (8). The number of sampling units required to reach the CAL for each method is shown in Figures 31 through 33. For line-intercept cover measurements in all strata, a sample unit is defined as a 1-m (3.3-ft) interval. For over-story density measures, the unit is a 100-m<sup>2</sup> (1089-ft<sup>2</sup>) circular quadrat. One-m<sup>2</sup> (10.84-ft<sup>2</sup>) quadrats for shrubs and 0.125-m<sup>2</sup> (1.36-ft<sup>2</sup>) quadrats for herbs, oriented on a belt transect, constitute sample units for density. Each variable radius point represents a basal area sample unit in the overstory.

371. The field sampling intensity used in Phase II actually reached the CAL in only about 50 percent of the sampling zones for both cover and density in the herbaceous stratum. Sampling intensity was most adequate in the overstory where the CAL was reached in about 67 percent of the instances. Sampling for shrubs was least adequate because CAL was reached in only 15 percent of the instances.

372. Required sampling intensities in Phase II ranged from 30 units to 40 units for line-intercept studies, 30 to 100 units (0.4 to 13.3 percent of area of zone) for belt-transect methods, and 3 to 10 units (30 to 100 percent of area) for overstory density and basal area determinations.

373. The curves shown in Figures 31 through 33 are in most cases inverse in pattern or slope to the vegetation abundance patterns. CAL generally was reached with fewer sample units in those instances where vegetation was most abundant.



**Figure 31.** Field sampling effort required for a 15% CAL for overstory density (-), cover (—), and basal area (...) for each 10-m-wide zone starting from the lower end (Zone 1) of the sampling site.

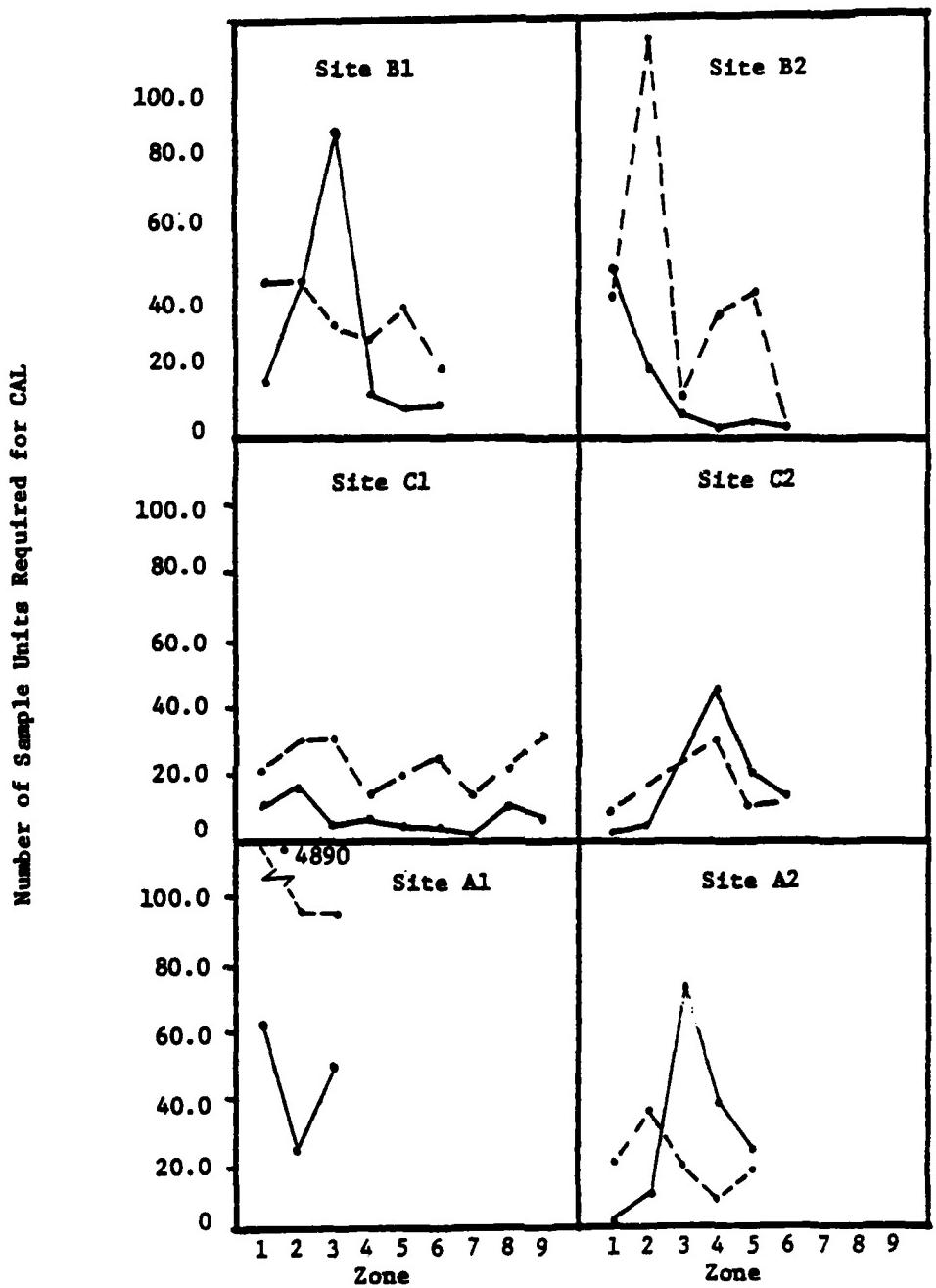


Figure 32. Field sampling effort required for a 15% CAL for shrub density (-) and cover (—) for each 10-m-wide zone starting from the lower end (Zone-1) of the sampling site.

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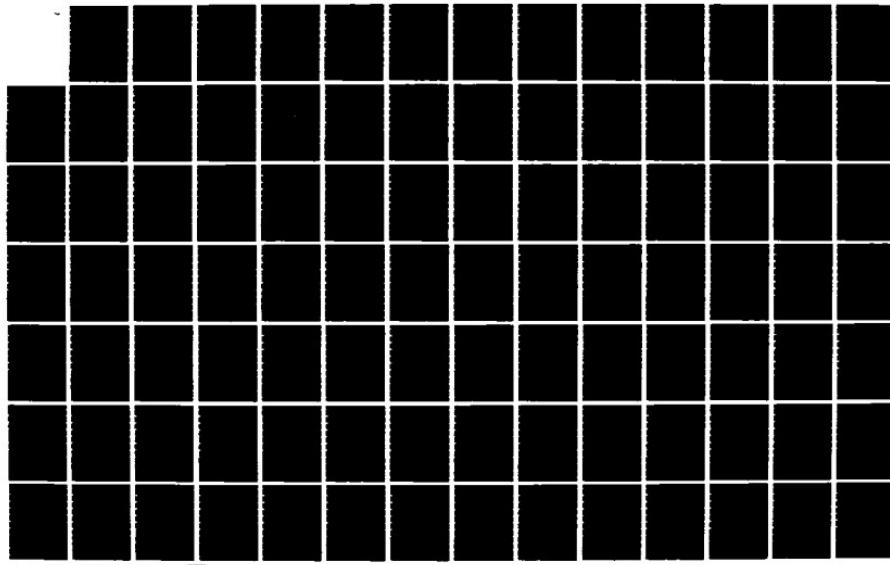
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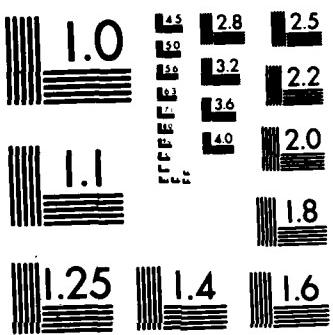
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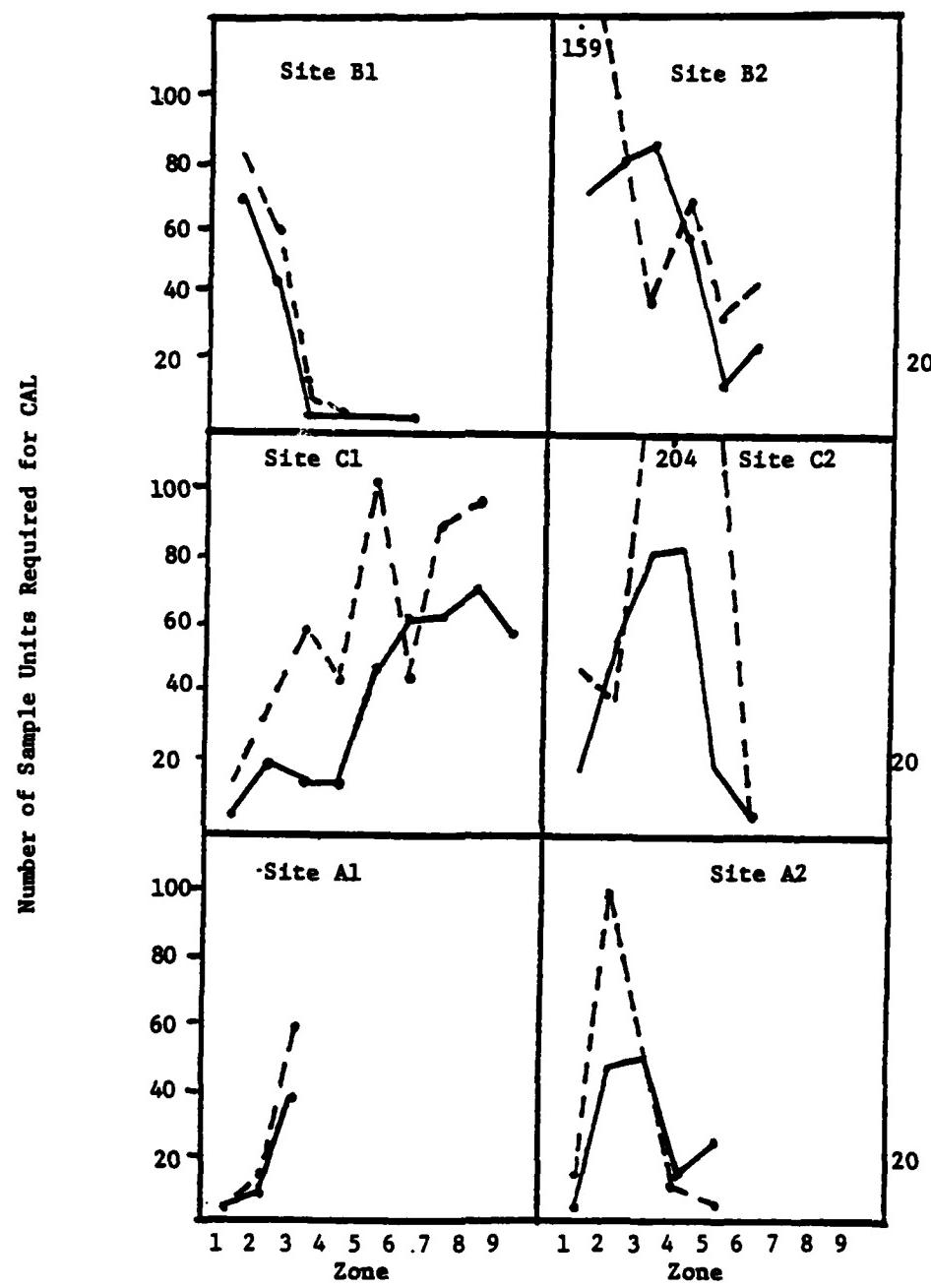


Figure 33. Field sampling effort required for a 15% CAL for herbaceous density (—) and cover (---) for each 10-m-wide zone starting from the lower end (Zone 1) of the sampling site.

### Vegetative Characteristics

374. Each of the six Phase II sites showed a floristic similarity to at least one of the Phase I sites. As shown in Table 29, the structural characteristics of the vegetation were generally similar to those found during Phase I. Density values in the overstory, where applicable, averaged from 67 to 1,500 stems/ha, which were within the range of 5 to 1,830 stems/ha found in Phase I sampling.

375. Density and cover values in the herbaceous strata were similar in Phase II (0 to 336 stems/m<sup>2</sup> or 0 to 120 percent) to those found in Phase I (5 to 875 stems/m<sup>2</sup> or 1 to 93 percent). Although total density values in the shrub strata showed a wider range than in Phase I (111 to 11,666 stems/ha versus 1,916 to 8,343 stems/ha), the maximum percent cover values were lower (120 percent versus 193 percent).

376. The number and type of species found within similar zones and vegetation types were also similar in both phases. These data tend to support the preliminary conclusions that the natural plant communities of the study area tend to fall into a relatively small number of vegetation types or associations.

377. Appendix Tables C1 through C6 show the species compositions based on the relative importance or dominance of each species in each 10-m-wide sampling zone of the sites. The measure of importance used is the Importance Value (IV). For the over-story stratum, the IV is an average of the relative density (RD), relative cover (RC), and relative dominance (RDo) for each species. For the shrub and herbaceous strata, the IV represents the average of RD and RC only.

378. When values are expressed as a percentage of the value found in the sampling zone with the highest values, the trends from sampling zone to sampling zone are consistently identified by all of the vegetative parameters chosen (density, cover, basal

**Table 29**  
**Structural Characteristics of Each Vegetation Stratum at the Phase II Sampling Sites**

Site and Stratum	Parameter	Sampling Zone									
		Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m	
<b>Site A1</b>											
<b>Overstory</b>											
Density	350.0	800.0	650.0	--	--	--	--	--	--	--	
Cover**	20.0	153.3	203.4	--	--	--	--	--	--	--	
Basal Area†	9.5	12.6	12.6	--	--	--	--	--	--	--	
Species Number	4	11	11	--	--	--	--	--	--	--	
H'††	0.34	0.84	0.93	--	--	--	--	--	--	--	
<b>Shrub</b>											
Density	111.1	444.4	444.4	--	--	--	--	--	--	--	
Cover	1.5	4.2	3.5	--	--	--	--	--	--	--	
Species Number	1	3	2	--	--	--	--	--	--	--	
H'	0.00	0.43	0.30	--	--	--	--	--	--	--	
<b>Herb</b>											
Density	76.9	66.6	53.8	--	--	--	--	--	--	--	
Cover	92.4	51.6	17.1	--	--	--	--	--	--	--	
Species Number	13	17	16	--	--	--	--	--	--	--	
H'	0.74	1.04	0.65	--	--	--	--	--	--	--	
<b>Site A2</b>											
<b>Overstory</b>											
Density	0.0	333.3	833.3	66.7	166.5	--	--	--	--	--	
Cover	30.0	137.5	220.0	112.5	152.5	--	--	--	--	--	
Basal Area	0.0	6.6	13.5	2.2	2.9	--	--	--	--	--	
Species Number	2	7	11	8	9	--	--	--	--	--	
H'	0.24	0.51	0.79	0.70	0.75	--	--	--	--	--	
<b>Shrub</b>											
Density	900.0	275.0	500.0	375.0	275.0	--	--	--	--	--	
Cover	2.5	2.5	3.5	5.3	0.6	--	--	--	--	--	
Species Number	1	1	6	6	5	--	--	--	--	--	
H'	0.00	0.00	0.62	0.45	0.56	--	--	--	--	--	
<b>Herb</b>											
Density	93.5	122.4	21.3	62.4	51.1	--	--	--	--	--	
Cover	80.4	59.0	24.6	49.8	48.1	--	--	--	--	--	
Species Number	12	9	26	30	33	--	--	--	--	--	
H'	0.68	0.61	1.07	1.08	1.18	--	--	--	--	--	

(Continued)

(Sheet 1 of 3)

Table 29 (Continued)

Site and Stratum	Parameter	Sampling Zone								
		Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Site B1</b>										
Overstory	Density	777.8	862.5	790.0	590.0	622.2	611.1	--	--	--
	Cover	51.0	56.0	54.3	60.5	45.3	63.8	--	--	--
	Basal Area	17.2	21.4	22.0	19.3	18.1	18.7	--	--	--
	Species Number	13	15	15	15	12	12	--	--	--
	H'	0.82	0.88	1.00	0.95	0.90	0.94	--	--	--
Shrub	Density	900.0	1,500.0	1,400.0	1,500.0	1,200.0	2,300.0	--	--	--
	Cover	3.3	4.2	4.0	26.5	19.2	10.0	--	--	--
	Species Number	4	5	6	8	4	6	--	--	--
	H'	0.46	0.38	0.60	0.69	0.40	0.55	--	--	--
Herb	Density	77.6	142.3	206.1	208.9	335.6	276.4	--	--	--
	Cover	23.2	36.5	55.8	63.3	98.8	86.2	--	--	--
	Species Number	17	16	21	19	16	18	--	--	--
	H'	0.61	0.50	0.35	0.29	0.22	0.26	--	--	--
<b>Site B2</b>										
Overstory	Density	1,320.0	--	1,160.0	--	1,280.0	--	890.0	--	--
	Cover	103.5	--	127.5	--	110.5	--	116.0	--	--
	Basal Area	30.3	--	15.2	--	13.5	--	6.5	--	--
	Species Number	13	--	15	--	16	--	9	--	--
	H'	0.86	--	0.35	--	0.80	--	0.73	--	--
Shrub	Density	1,333.3	333.3	7,332.6	7,999.2	5,666.1	7,332.6	7,000.0	--	--
	Cover	5.0	6.3	24.3	51.2	35.5	45.7	44.3	--	--
	Species Number	2	3	7	11	16	19	17	--	--
	H'	0.26	0.30	0.49	0.62	1.04	1.01	0.83	--	--
Herb	Density	44.9	28.8	10.3	15.1	61.5	48.5	--	--	--
	Cover	25.5	21.7	10.7	21.0	62.2	46.3	--	--	--
	Species Number	23	27	20	31	55	53	--	--	--
	H'	0.77	0.98	1.06	1.19	1.46	1.47	--	--	--

(Continued)

(Sheet 2 of 3)

Table 29 (Concluded)

Site Cl		Sampling Zone								
		Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<u>Overstory</u>										
	Density	420.0	—	360.0	—	580.0	—	600.0	—	520.0
	Cover	16.7	53.3	50.0	106.7	106.7	150.0	93.3	140.0	150.0
	Basal Area	3.4	—	1.0	—	10.1	—	15.5	—	17.9
	Species Number	0.59	0.49	0.49	—	6	—	7	—	5
	H'	—	—	—	—	0.61	—	0.68	—	0.46
	Shrub	6,333.3	3,999.6	3,999.6	7,665.9	6,999.3	4,332.9	11,665.5	5,332.8	4,995.5
	Cover	23.7	14.8	34.0	20.8	33.7	44.2	53.0	25.5	24.2
	Species Number	4	3	6	5	4	2	4	8	5
	H'	—	—	—	—	0.39	0.24	0.08	0.61	0.52
	Herb	93.5	70.0	47.3	57.3	25.9	18.8	16.4	13.4	24.3
	Cover	120.0	120.0	89.7	68.4	30.8	35.1	23.3	42.7	33.2
	Species Number	17	19	15	10	8	12	11	13	12
	H'	—	—	—	—	0.46	0.46	0.63	0.81	0.78
<u>Site C3</u>										
<u>Overstory</u>										
	Density	1,500.0	2,333.3	1,767.7	1,166.7	1,300.0	866.7	—	—	—
	Cover	100.0	183.3	180.0	150.0	196.7	203.3	—	—	—
	Basal Area	33.8	46.7	42.7	36.2	41.0	29.8	—	—	—
	Species Number	5	6	4	2	4	6	—	—	—
	H'	—	—	—	—	0.38	0.55	—	—	—
	Shrub	7,250.0	2,500.0	2,000.0	2,000.0	3,250.0	5,750.0	—	—	—
	Cover	59.8	32.3	4.4	7.9	6.9	23.5	—	—	—
	Species Number	2	4	3	3	5	—	—	—	—
	H'	—	—	—	—	0.48	0.55	—	—	—
	Herb	22.6	9.2	0.3	0.0	1.8	40.4	—	—	—
	Cover	6.8	1.5	0.5	0.3	1.3	22.4	—	—	—
	Species Number	6	5	3	1	10	26	—	—	—
	H'	—	—	—	—	0.90	0.99	—	—	—

\* Density in stems per ha for overstory and shrub, and in stems per 1 m<sup>2</sup> for herbaceous vegetation.

\*\* Cover as percentage ground projection.

† Basal area of stems in m<sup>2</sup> per ha.

†† H' is species diversity calculated by Shannon-Weaver Diversity Index.

Source: ESE, 1981.

(Sheet 3 of 3)

area). Agreement was particularly good for the two herbaceous stratum methods. Agreement was less consistent in the overstory and shrub strata.

379. In the shrub strata, the density and cover values showed similar trends, but were complicated by other factors. In some cases (Sites B1, C2, and A2), the magnitude of the variation was greater in the cover parameter than in the density parameter. Occasionally, values for individual sampling zones (for example, Site B1, Zone 7) showed no agreement between methods. The instances where these aberrant patterns showed lack of agreement do not appear to be correlated to density, cover, or species number. They are probably due to random variation related to particular instances of aggregation or clumping of vegetation.

380. In most instances, there was good agreement among parameters for the overstory stratum. In three sites (B2, C1, and A1), the basal area values showed magnitudes of variation inconsistent with those in density and cover. In one instance (Site C2), the density value deviated.

381. Although there appears to be no clear explanation for the trend in the single-density aberration, each case of basal area deviation may be explained by characteristics of the vegetation at the particular site, and will be discussed later.

382. In general, the zonal abundance patterns are consistent for wetland types (i.e., marsh or swamp). Total overstory density and cover showed low zonation along the gradients from swamp to upland forest. In both shrub- and herb-dominated wetlands, overstory cover increased along the gradient but density and basal area patterns were more variable. Herbaceous and shrub abundance patterns are less consistent. Patterns for these strata appear to be site-specific, and may be related to tree cover, elevation or slope, and hydroperiod.

### Vegetative Delineation

#### Community parameters

383. Although the degree of consistency among the various abundance parameters (density, cover, basal area) was high with respect to identification of trends within sites and of relationships among zones within each site, there was a lower degree of consistency of pattern among sites. These results (Table 30) indicate that patterns of abundance along wetland-upland gradients in the region may not be sufficiently consistent to use as definition or delineation criteria.

384. As might be expected, herbaceous vegetation was found to decrease along the gradient from marshes and shrub-dominated marshes to uplands (Sites A1, A2, and C1), while overstory abundance decreased. Shrub patterns along the marsh-to-upland gradient varied. Shrub density and cover peaked in the transition of lower upland zones in two sites (A1 and C1), but in the third (A2), cover peaked in the wetlands while density peaked in the transition-upland range. In Phase I sampling, cover and density did increase toward the upland in one marsh site (A), while density peaked in the wetland and cover in the transition zone at one site (C).

385. Abundance patterns along gradients from shrub- or tree-dominated forested wetlands were varied. Overstory abundance remained virtually unchanged in Site B1, indicating a homogenous community. Shrub and herb patterns at Site B1, however, showed definite increases toward the upper end of the gradient. At Site B2, shrub patterns indicated a distinct break between Zones 2 and 4, while overstory patterns showed no breaks, and herbaceous patterns indicated possible breaks between Sampling Zones 2 and 3, and Sampling Zones 4 and 5. At Site B (Phase I), abundance of trees decreased, abundance of herbs increased, and abundance of shrubs remained virtually unchanged along the gradient.

Table 30  
Trends in Abundance and Species Diversity Patterns Along  
Wetland to Upland Gradients in Nine Sites\*

Parameter Group	Site	Herbaceous Wetlands			Site	Forested Wetlands		
		Tree	Shrub	Herb		Tree	Shrub	Herb
Abundance	A	++↑	++	--	B	--	00	++
	C	++	--	--	B1	00	++	++
	A1	++	++	--	B2	00	++	--
	A2	--	--	--	C2	0-	-+	--
	C1	++	++	--				
Species richness and diversity	A	++	+-	++	B	+-	+-	+-
	C	+-	++	++	B1	00	00	-
	A1	++	+-	+-	B2	00	++	++
	A2	++	+0	++	C2	-+	++	--
	C1	00	00	00				

\* First notation in pair shows trend from wetland to transition zones; second notation shows trend from transition to upland zones.

↑ + = increasing in value  
 - = decreasing in value  
 0 = no substantial change in value

Source: ESE, 1981.

386. In the buttonbush-dominated shrub swamp (C2), both shrub and herb abundance decreased from the wetland, reaching a minimum at the presumed upper edge. Both strata then increased greatly with further progression toward the upland zone.

387. Species number (richness) and diversity ( $H'$ ) patterns usually were similar. In marsh-to-upland gradients (Table 30), both richness and diversity for all strata tended to increase outside of the wetland vegetation zones; peak values, however, occurred in both transitional and upland areas. Along gradients from forested wetlands, no consistent patterns occurred.

388. Various threshold levels were evaluated for the above-mentioned parameters. ESE researchers were not able to identify a specific threshold level which could be applied to all sites for any of the parameters tested. Threshold levels which correctly delineated vegetation zone boundaries at one site would lead to inaccurate delineations at other sites. These thresholds were attempted both for absolute values and for relative values when compared to other values along the gradients. None of the threshold values considered for density, cover, basal area, species richness, or species diversity was considered adequate for defining vegetation zone boundaries on a regional level.

389. Only for the overstory and herbaceous strata along gradients from marsh to uplands did there appear to be high degrees of consistency. Based on results in the three freshwater or intermediate marsh wetlands of Phase II, species richness levels in marshes of 10 to 20 herbaceous species per sampling zone and  $H'$  levels of 0.60 to 0.75 might be expected for the region. In contrast, the ranges in both forested wetlands and uplands may be 1 to 60 species with  $H'$  values of 0.00 to 1.45.

#### Similarity indices

390. Both quantitative ( $IS_{BC}$ ) and qualitative ( $IS_S$ ) similarity values, when expressed as the degree of similarity to

upper- or lower-most sampling zones of a transect, showed that distinct trends in species composition occurred at most sites. IS curves usually were similar for all three strata within a site; the quantitative and qualitative indices were also similar to each other.

391. Figure 34 shows  $IS_{BC}$  patterns for two typical sites. Each graph shows two lines. The line which always peaks at 100 percent in Sampling Zone 1 (wetland baseline) represents the degree of similarity of a zone to the wetland community. The second line, which peaks at the upper end of the gradient, represents similarity to the more upland conditions on the site. The use of a 1:1 ratio as an indicator between these two values generally was a fairly consistent and accurate indicator of the presumed center point of the transition zone when values for all strata and parameters were averaged. Individual values were not always consistent, especially for the shrub-dominated wetland at Site C1. Figure 34 shows curves for each stratum for Sites C1 and C2. The location on the gradient at which the two lines cross (1:1 ratio) for Site C2 is similar for each stratum (distance from baseline equaling 46 m to 52 m), whereas for Site C1 the range is much larger (18 m to 63 m).

392. No significant differences ( $P = 0.05$ ) between the  $IS_{BC}$  and the  $IS_g$  indices were found with respect to the location along the gradients at which the 1:1 ratio occurred. No significant differences in the location of this point were found among the three strata, although the mean distances for all six sites ranged from 32 m to 36 m.

393. Several threshold value criteria were evaluated for each method. Table 31 compares the upper and lower edges of a transitional vegetation zone as calculated by three IS threshold levels to the edges as subjectively estimated in the field. In this table, all values for herb, shrub, and overstory strata within each zone were averaged. The lower end of the transitional

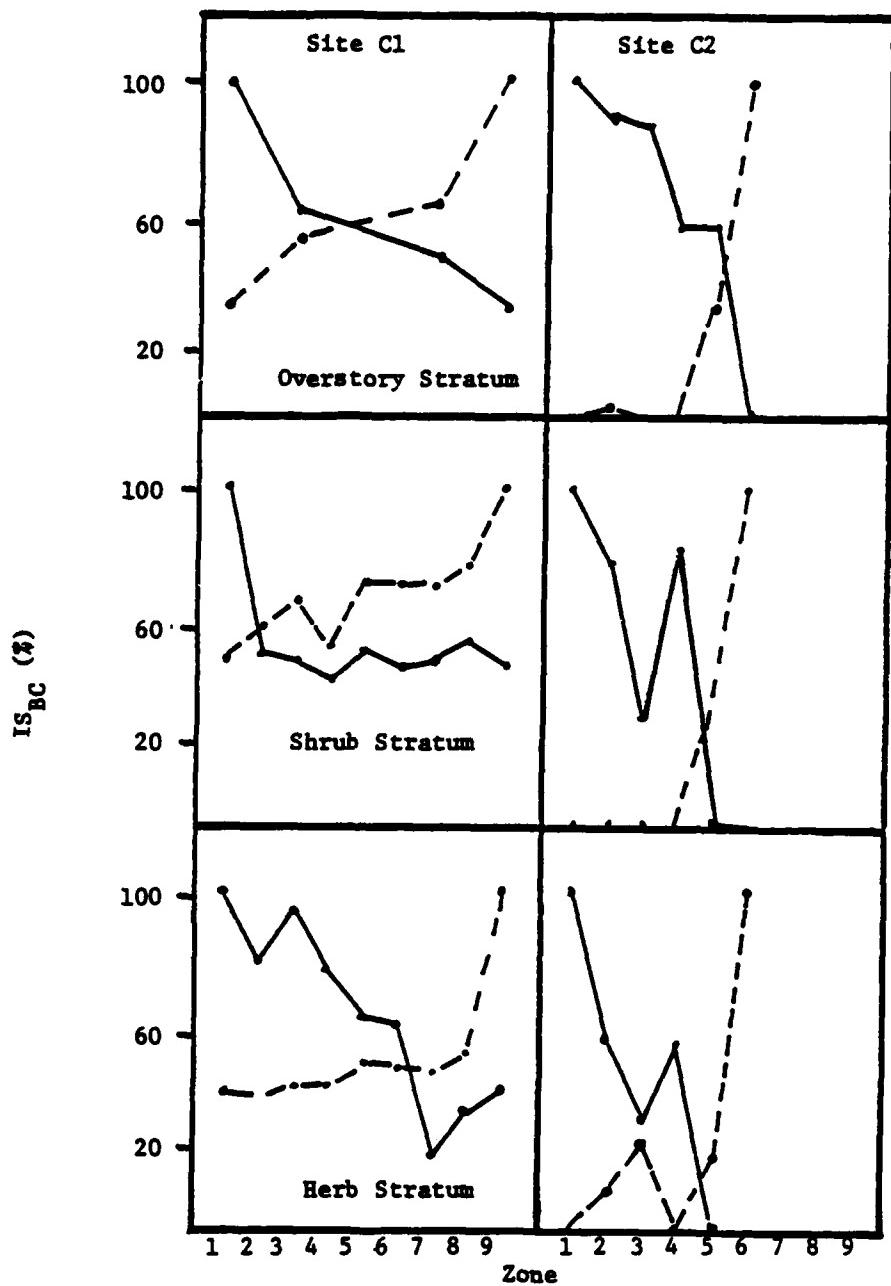


Figure 34. Similarity index patterns in two Phase II sites. Similarity to lowest (wetland) zone (-). Similarity to highest (upland) zone (—) for each 10-m-wide zone starting from the lower end (Zone 1) of the sampling site.

Table 31  
Estimated Limits of Transition Zone As Determined From  
ISBC Curves Using Three Threshold Levels

Site	Observed Limits of Transition Zone (m)*	Estimated Limits of Transition Zone (m)		
		80% Threshold	75% Threshold	70% Threshold
A1	15-20	15-27	16-27	18-26
A2	25-40	17-46	18-45	19-43
B1	22-35	21-43	22-36	23-30
B2	20-30	18-62	19-59	24-57
C1	15-85	25-84	26-83	29-69
C2	45-55	23-56	23-56	25-56

---

\* Distance from lower baseline in m.

Source: ESE, 1981.

zone was determined by threshold values on the wetland IS<sub>BC</sub> line and the upper end by the same threshold level applied to the upland IS<sub>BC</sub> line of the graphs. For three of the six sites, a 70-percent threshold value appears to best approximate the observed range. However, 4 of the 12 boundary delineations are substantially in error (over 25-percent deviation from observed value) as opposed to only two errors each for the 80-percent and 75-percent thresholds.

394. Use of a minimum-level threshold was evaluated as well. In many instances, 30 percent was a representative cut-off level for delineations. However, since minimum values at several sites were above 30 percent, the level was not applicable for all sites and was eliminated as a possible criterion.

395. Comparison of similarities of adjacent sampling zones in several cases indicated locations of significant dissimilarity which often corresponded to presumed locations of transition zone boundaries. However, in an equal number of occurrences, such dissimilarities appeared to bear no relation to these boundaries. There were no consistent differences or threshold values which allowed interpretation of patterns without substantial additional knowledge of the site.

#### Species indicator groups

396. Groups of potential indicator species were established using species adaptation number (SAN) values as parameters of wetland or upland tolerance. The number of species to be used in each tolerance group was first established on the basis of the aggregate response to both upland and wetland conditions combined species adaptation number (SAN<sub>C</sub>). Values of SAN<sub>C</sub> above 2.50 were chosen to represent species in the wetland group; values below 0.50 indicated upland species, and all remaining species were defined as the transitional group.

397. Once the three groups were defined for the SAN<sub>c</sub> parameter, the number of species in each group was counted, and groupings were made for the SAN<sub>w</sub> and SAN<sub>u</sub> parameters using the same number of species. Species composition was different for each parameter because the species were ranked separately on the basis of each parameter.

398. Figure 35 shows the total importance value (IV) for each group. Shown in the figure are the same data expressed using the SAN<sub>w</sub> parameter (top), the SAN<sub>u</sub> parameter (middle), and the SAN<sub>c</sub> parameter (bottom). Results shown are for the overstory stratum at two sites. The patterns and inferences from other sites and strata all were similar to these.

399. Although each method is based upon equal species numbers in each group and upon species rankings along wetland-upland gradients, the resultant figures show great variation in the relative importance of each group. The results based on the wetland adaptation numbers (SAN<sub>w</sub>) emphasize the dominance of the wetland group. The opposite is true for the upland adaptation parameter (SAN<sub>u</sub>). Results from such methods are therefore highly dependent upon the parameters used to construct the groupings.

400. Patterns based on SAN<sub>u</sub> values are much different from those of the other parameters; however, even these other parameters are not entirely consistent. For example, the patterns for the SAN<sub>w</sub> and SAN<sub>c</sub> groupings are similar for Site C2, yet both pattern and absolute magnitude are altered at Site Cl. Of the six Phase II sites, similar patterns were noted at only three sites (A1, A2, and C2). No consistency of pattern could be ascertained, and no ratio or threshold criteria were found which produced consistent delineation patterns among several sites.

401. Indicator group results for different strata showed poor agreement in patterns. In general, shrub and herb results emphasized the importance of transition and upland species groups

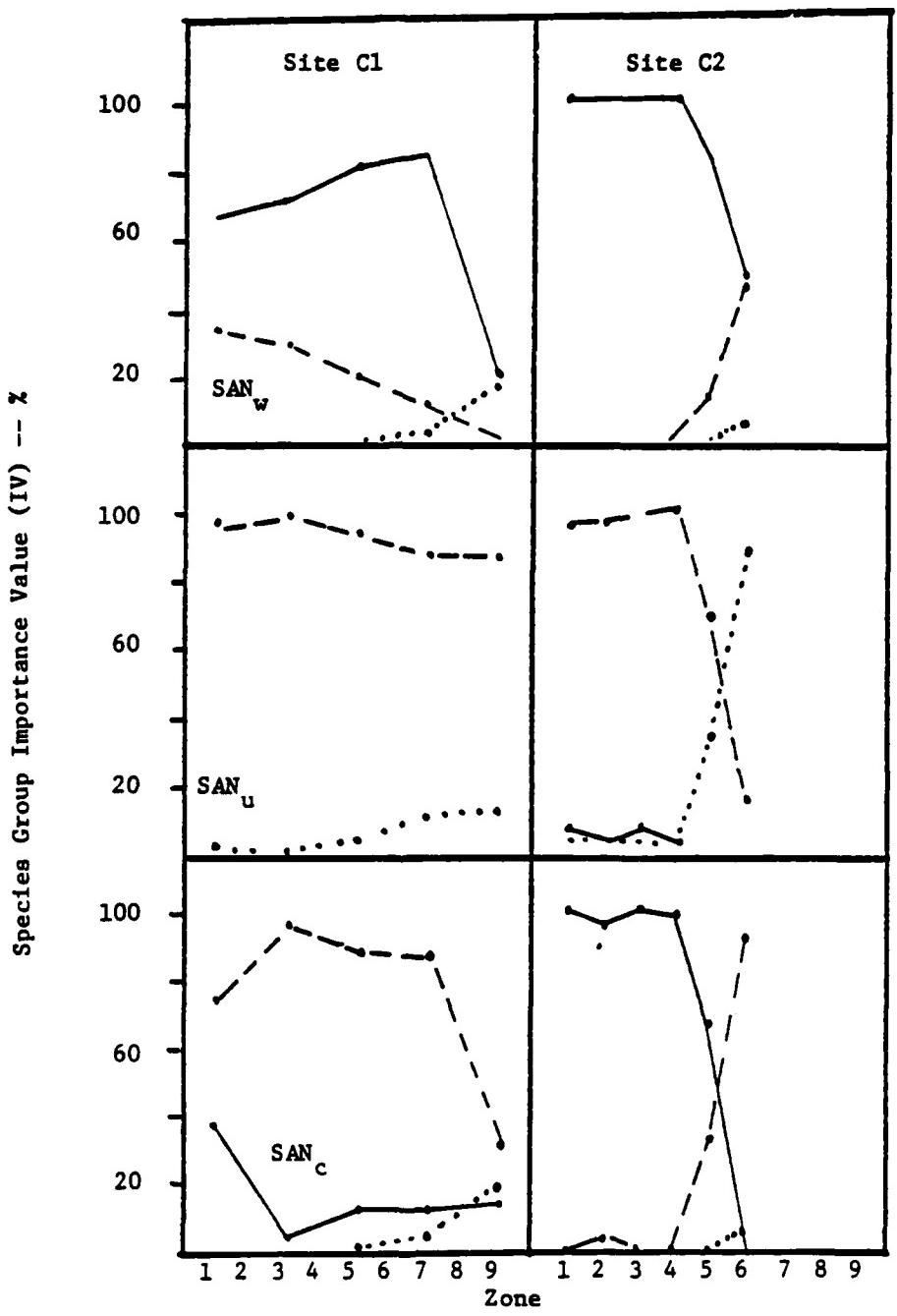


Figure 35. Relative dominance of wetland indicator species group (—), transitional species group (---), and upland species group (···), measured by IV, for overstory strata. Species groups determined by SAN<sub>w</sub> rankings (top), SAN<sub>u</sub> rankings (middle), and SAN<sub>c</sub> rankings (bottom) for each 10-m-wide zone starting from the lower end (Zone 1) of the sampling site.

over the wetland group to a greater degree than did the overstory data.

#### Continuum indices

402. For all sites, the continuum index (CI) values provided a measure of the degree of wetland tendency of sampling zones within each site. Values generally decreased continually with increasing distance away from the wetland baseline. Figure 36 shows the patterns for the overstory CI values at four representative sites calculated from six different sets of parameters (see Table 28). These patterns are similar to those of the IS values. In some cases, such as at Site C2, the CI values do not change as rapidly as do the IS values. In most instances, the trends shown by all methods are similar. The primary difference among the methods lies in the slope or steepness of the curves. The  $CI_v$  methods usually showed the largest percentage decreases (steepest slopes) across gradients, followed by the  $CI_c$  methods. The least amount of decrease was shown by the  $CI_w$  methods. Use of quantitative data ( $\Sigma SAN \cdot IV$ ) rather than presence/absence qualitative data ( $\Sigma SAN/N$ ) tended to result in lesser slopes.

403. When CI values are presented graphically (see Figure 36) as a percentage of maximum value, threshold values were not satisfactory for defining zones. Threshold values necessary to delineate the observed wetland boundaries shown in Table 31 ranged from 60 to 98 percent; threshold values for delineation of upland boundaries ranged from 44 to 98 percent. With such wide ranges and such overlap in values, the threshold concept does not appear to be valid when used for relative CI values within sites.

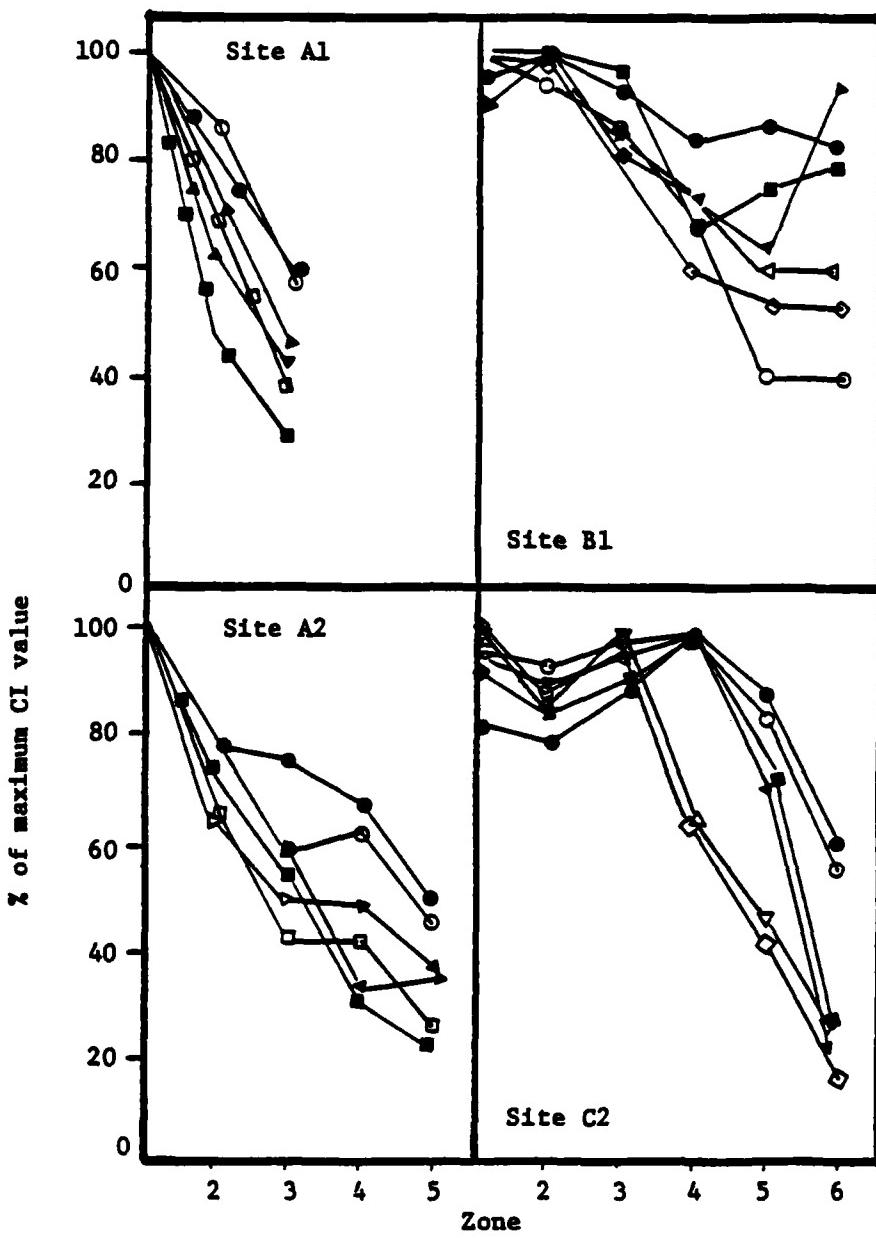


Figure 36. Continuum index value patterns along four wetland-upland gradients. Shown are over-story values computed from six CI parameters:

$CI_{w-q1}$ (○)	$CI_{w-qn}$ (●)	$CI_{c-q1}$ (□)
$CI_{c-qn}$ (■)	$CI_{v-q1}$ (△)	$CI_{v-qn}$ (▲)

for each 10-m-wide zone starting from the lower end (Zone 1) of the sampling site.

PART VI: PHASE II STUDY--ANALYSIS AND DISCUSSION

Verification of Sampling Efficiency

404. During Phase I, the level of effort spent in field sampling was not always sufficient to reach a CAL, which then had to be estimated by Equation (8) (see Part II, Page 15). The Phase I effort generally was sufficient to reach a CAL for the overstory stratum, but was less sufficient for herbs and only rarely sufficient for the shrub stratum. The same pattern was repeated in Phase II, even though the percentage of time allocated to shrub and herb sampling was increased. These results imply that under field conditions, a 15-percent CAL is rarely reached for shrubs and that this stratum is often under-sampled. Results indicate that equal time should be given to shrub and tree sampling and about 50 percent of that amount used for herb sampling if the primary objective is to provide results of equal variability.

405. The ranges of sampling effort required for Phase II sites were equivalent to those of Phase I (Table 32). The primary exception was in the shrub stratum where some estimated CAL values (Sampling Zone 3 of Sites B1 and A2) were significantly above predictions and would have required sampling up to 90 percent of a sampling zone. Neither of these sampling zones was apparently different in structure from adjacent sampling zones, although increased aggregation or clumped distributions in these areas may have caused the abnormal variation.

406. Although in a few sampling zones the level of effort required to reach a CAL was higher than predicted, most were lower. Figure 37 compares some actual efforts to efforts predicted using the Phase I density-effort regressions of Figures 17 and 24. Data from other methods were too variable to be used for comparisons. The diagonal line in the figures

**Table 32**  
**Actual vs. Predicted Minimal Sample Area for 15-Percent SEM**  
**for Phase II Density Determinations**

Zone	Dominant Strata	Required Sampling Area (m)					
		Overstory Stratum		Shrub Stratum		Herb Stratum	
		Predicted	Actual	Predicted	Actual	Predicted	Actual
Wetland	Herb	--	7-22	123	20-600	1.3-3.8	0.6-6.3
Transition	Shrub	40	5-10	123	20-450	1.5-12.5	1.2-8.8
Transition	Tree	40	7-30	--	100-900	2.8-11.5	0.6-11.3
Upland	Tree	5-10	7-30	196	50-200	2.8-11.5	0.6-5.0
Wetland	Tree	5	7-30	40	100-700	22.0	10.0-11.5

Source: ESE, 1981.

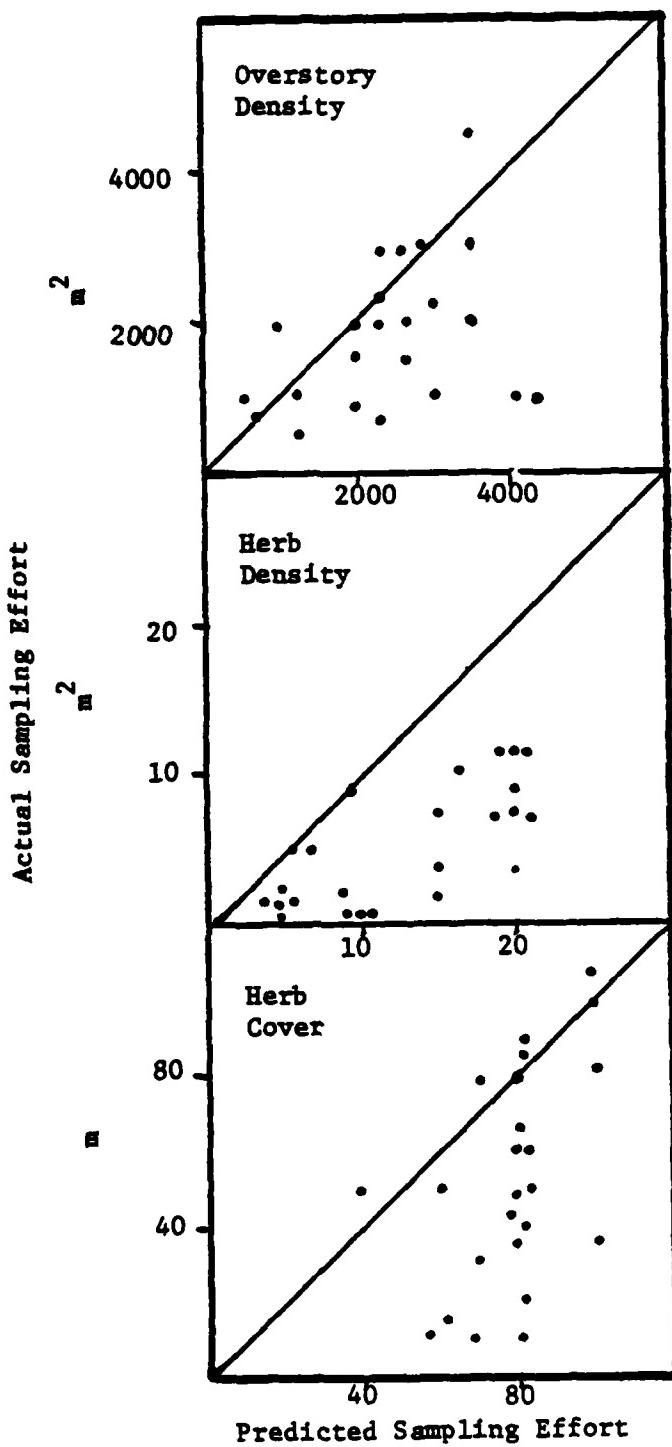


Figure 37. Comparison of actual Phase II sampling efforts to levels predicted by Phase I results.

represents the level at which actual effort equals predicted effort. All points below the line indicate zones where less sampling time was required than was predicted. In the majority of cases, less effort was required than was predicted.

407. Prediction of levels required for adequate sampling remains difficult; however, the predicted values from Phase I appear to be conservative and remain sufficient for adequate sampling in most situations. The Phase II results in this sense do verify the conclusions reached in Phase I.

Vegetative Characteristics of Sampled  
Louisiana Transition Zones

408. Table 33 summarizes vegetation structure found for various physiognomic types in the southern Louisiana region. These characteristics may not be typical of all wetlands since sites were selected near wetland boundaries. True saline systems are not represented since these communities rarely grade directly into uplands in this region.

409. Species richness and complexity tend to increase from wetlands to uplands. The forested uplands appear to support more herb species and numerous tree and shrub species. The high herbaceous richness of these uplands is explained by successional status. Highest richness (more than 50 species) was found in two upland zones of Site B2, where a late-successional, old field community was present. Other high values (20 to 33 species) occurred in intermediate zones of Sites B, B2, and A2, where less recently disturbed but still young, successional communities occur.

410. Wetlands generally had low species richness. Highest values in wetlands were in fresh marshes where 10 to 20 species were present per zone. More stressful environments such as the

**Table 33**  
**Ranges of Vegetative Characteristics Associated**  
**with Louisiana Plant Communities**

Vegetative Parameter	Herb-Dominated Wetlands		Shrub-Dominated Wetlands and Transition Zones		Forested Wetlands and Transition Zones		Forested Uplands	
	Overstory Stratum	Shrub Stratum	Basal Area (m <sup>2</sup> /ha)	Species Number	Cover (%)	Density (#/ha)	Cover (%)	Density (#/ha)
Density (#/ha)	0-800	0-2300	0-106	2-6	0-183	0-900	0-5	77-875
Cover (%)	0-106	10-183	0-10	2-6	19-46	4-65	0-5	51-97
Basal Area (m <sup>2</sup> /ha)	0-10	19-46	0-10	2-6	0-7	7-8	0-4	3-17
Species Number	2-6	0-7	0-7	0-7	17-68	10-24	7-8	1-28
Shrub Stratum								
Density (#/ha)	0-900	3000-7200	0-5	0-4	4-65	3000-7200	0-5	77-875
Cover (%)	0-5	4-65	0-4	0-4	7-8	500-6900	5-36	51-97
Species Number	0-4	2-35	0-4	0-4	7-8	500-6900	2-35	3-17
Herb Stratum								
Density (#/m <sup>2</sup> )	0-410	0-100	0-193	1-28	0-410	0-100	25-104	0-410
Cover (%)	0-193	25-104	1-28	1-28	0-193	25-104	1-99	0-193
Species Number	1-28	10-23	1-28	1-28	1-28	10-23	16-55	1-28

Source: ESE, 1981.

brackish marsh of Site A had few species and were essentially monospecific.

411. Overstory density was highest in forested uplands, where values of more than 1,000 stems/ha appear to be characteristic. On the basis of vegetative structure, bottomland hardwoods communities appear to be more closely allied to upland forests than to deep swamps, such as cypress-tupelo-gum swamps. Overstory density, basal area, and cover are in the moderate range, as they are in mixed and oak-pine uplands. Upland forests tend to have higher overstory cover than either bottomland hardwoods or deep swamp communities. Bottomland hardwoods and some uplands containing pines may have low cover values in proportion to other parameters because of the low canopy coverage of the pines.

412. Basal area values were characteristically greater in forested wetlands. However, at the sites studied, these higher values are due more to the age of the stand and to the time since trees were last cleared than to a direct effect of hydric conditions.

413. Sites B2 and C2 illustrate how factors other than natural hydric conditions affect zonation. The vegetation pattern at Site B2 contains four separate age/community types, including a floodplain cypress-tupelo-gum swamp which has not been cut for at least 70 years, a valley-floor bottomland hardwood community of like age, an upland mixed forest last cleared 30 to 60 years ago, and an old field invaded by spruce pines which was abandoned no more than 15 years ago.

414. Site C2 is located on a mudflat created when Lake Chicot was impounded. Before impoundment, there was a maple-ash-tupelo-gum swamp community. Today the wetland zones visually appear to be dominated by a single shrub species, buttonbush. The dense overstory is masked by the shrubs until quantitative sampling is undertaken. A major successional change has occurred here. Reproduction of the dominant overstory trees is almost

nonexistent. Although the mature trees can tolerate the present hydroperiod, young, shorter individuals are eliminated by the extreme water fluctuations, so that only a few species like buttonbush can invade. As a result, the zonation patterns at Site C2 are atypical of those usually encountered in natural transition zones.

415. Secondary influences and patterns such as those at Sites B2 and C2 must be recognized and described when various parameters are presented for wetlands delineation studies.

416. The plant communities sampled in this study are similar to those reported for the region by other authors. Penfound and Hathaway (1938) reported a cypress-tupelo-gum swamp in which bald cypress had an estimated IV of about 40 percent. Pumpkin ash, tupelo-gum, black gum, and red maple were major associated species. Our wetland zones at Sites B and B2 were similar in composition.

417. Chabreck (1972) reported that few species occur in brackish marsh, with only Spartina patens and Distichlis spicata comprising over 5 percent of dominance. Site A of the ESE study is representative of this type.

418. Spartina patens and Sagittaria falcata are major components of coastal fresh and intermediate marshes. Overall compositional differences were slight, with more species and a reduced dominance of S. patens in the fresh marsh. Our marsh Sites C and C1 were typical of intermediate and fresh coastal marshes, respectively. Sites A1 and A2 were typical of the deepwater fresh marshes described by the Environmental Laboratory (1978).

#### Distribution of Species Along Wetland Gradients

419. Figure 35 shows zonation among sites based on results of several methods of developing indicator species lists.

Although all of the methods shown were developed using the same criteria and procedures, it is obvious that the choice of parameters (derivation of SAN values) and the resulting species grouping had a major effect on results.

420. This observation points out the presence of some large problems which must be confronted when defining community types and when using indicator species concepts. These problems have been subjects of a major field of ecological research over the past 50 years and can be summed up in the question, "Do plant species occur as elements of discrete aggregated communities with specific habitat requirements, or do species exist along a continuum of environmental conditions such that each species has its individual and independent patterns of response?"

421. In 1951, Curtis and McIntosh provided major support for the continuum concept when they demonstrated that individual species do have minimum, optimum, and maximum points of development along environmental gradients and that each species reaches optimum development in stands for which the position is fixed in relationship to other species. Extensive research in the fields of physiological ecology and mathematical ecology have since provided overwhelming evidence that species do occur along such a continuum to which they have varying degrees of adaptation.

422. If we accept the thesis that species occur independently along a wetland-to-upland continuum, then a decision must be made as to which criteria will be used for boundary delineation if distinct species assemblages do not occur. Are there significant species groupings with similar relative positions along the continuum such that an indicator group still can be defined?

423. One approach to this question is to graph the distribution of species occurrence along gradients or transects as shown in Figure 38. If distinct assemblages do occur, then

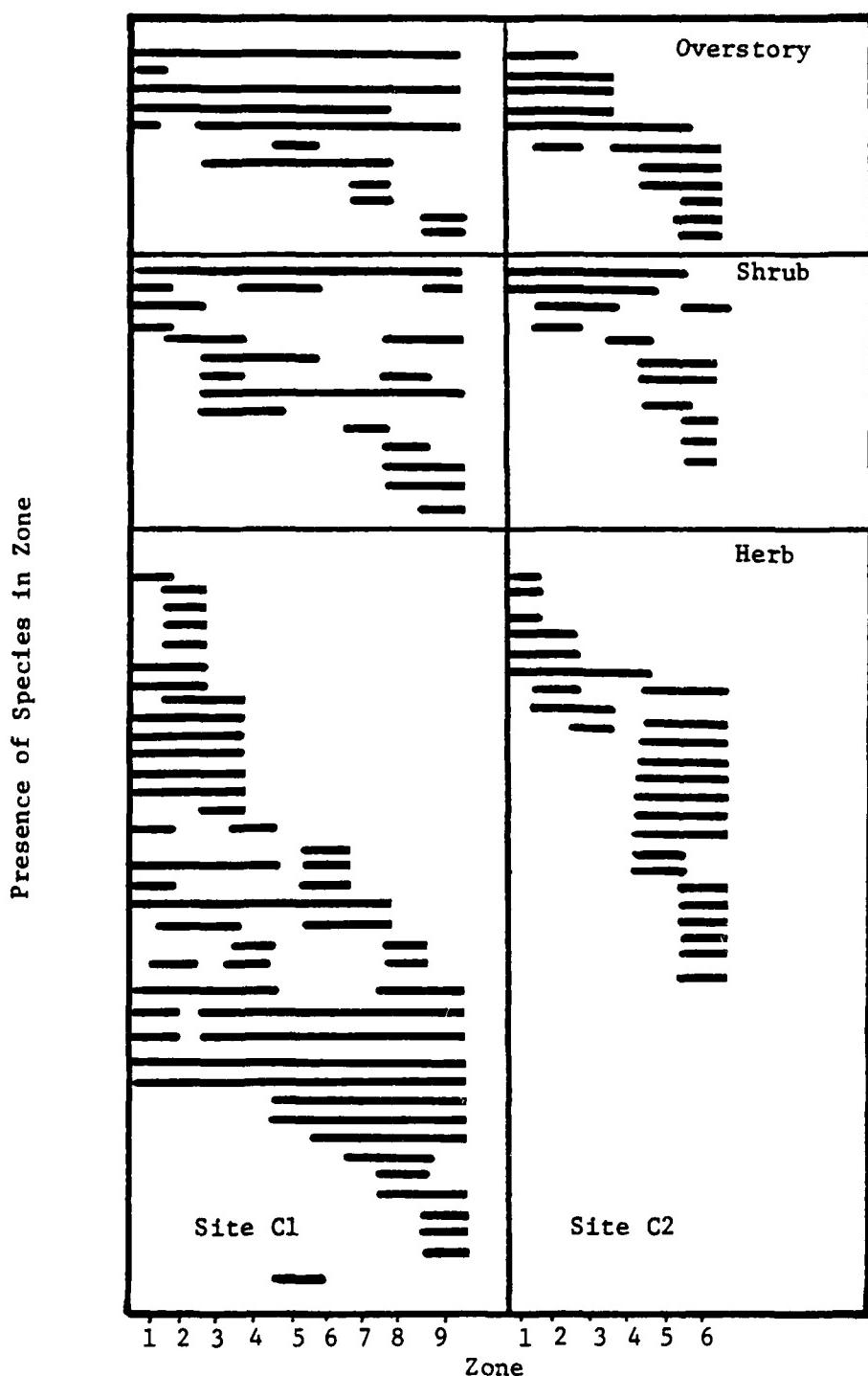


Figure 38. Occurrence of species along transects at Sites C1 and C2. Results presented in same order as species lists in Appendix Tables C5 and C6.

species in such groups should have similar responses to the gradient, as occurs in Site C2. At Site Cl, however, there was little distinct grouping. Those species which did distinctly segregate are so low in dominance as to be almost negligible in quantitative studies.

424. If species do occur in distinct aggregations, then the group should show substantially identical responses or tolerances to upland gradients as well as to wetland gradients. Figure 35 indicates that this aggregation did not occur at these sites. Groups of species with similar wetland tolerances did not respond similarly to upland conditions, thus leading to the divergent patterns shown in Figure 35.

425. The SAN values used to develop the groups in Figure 35 are listed in Appendix C. These values are modeled after the CAN concept developed by Curtis and McIntosh, who first developed a scale to define the position of species along a continuum. The significant step in validating the continuum concept is the ability to arrange stands (or zones) along a gradient based solely upon species responses, irrespective of the fact that each species is independently distributed. Curtis and McIntosh (1951) developed the continuum index concept to do this. They state that the continuum index is a "measure of the total environment as expressed by the total species composition. Its main use is in ranking the stands [zones] along a gradient, such that those stands [zones] which are most similar from the standpoint of their trees are placed close together."

426. They state further that, "If the order of stands is phytosociologically correct, then the behavior of the individual species in these stands should follow reasonable patterns. If the order is wrong, then individual species would exhibit only chance variations and random fluctuations."

427. Curtis and McIntosh were proposing that the stands could be assigned relative numbers based on species composition.

If the resultant synthetic gradient were representative of an environmental gradient, then each species should have a minimum, optimum, and maximum point on the curve. A normal curve results if this is so. If the gradient is not representative, then importance values would be completely random and show no pattern.

428. When importance values for some species are plotted on the transects, as in Figure 38, patterns of increasing or decreasing abundance often occur.

429. Figure 39 illustrates the process of converting information like that in Figure 38 into the continuum index format. Continuum Index (CI) values for each zone were developed using the SAN and IV values for each species (also shown in Appendix C). For the CI concept to be applicable to Louisiana wetland gradients, a plot of IV values for indicator species along the CI gradient should fall into a pattern resembling a normal curve. Absence of a species is not a valid criterion for decision-making because a species which is capable of surviving in a location may be absent by chance. Likewise, minimum occurrence values are poor criteria. Plots of species occurrence along this gradient will not actually be in a straight line like a normal curve. Rather, the distribution will follow a Gaussian curve, which approximates the area under a normal curve. A line connecting the maximal values of the curve should approximate a normal curve.

430. All species found in Phases I and II were checked for distribution on a CI. Most of the species had either such limited frequency (less than four zones) or such limited IV as to be insignificant.

431. Figure 39 shows the distribution patterns of some of the more frequent and abundant species along continuum indices developed from  $SAN_w$  values using quantitative data ( $\Sigma SAN_w \cdot IV$ ). In general, species values follow Gaussian curve patterns. Further, these species have individual minimum, optimum, and maximum values on the gradient, thus supporting the contention

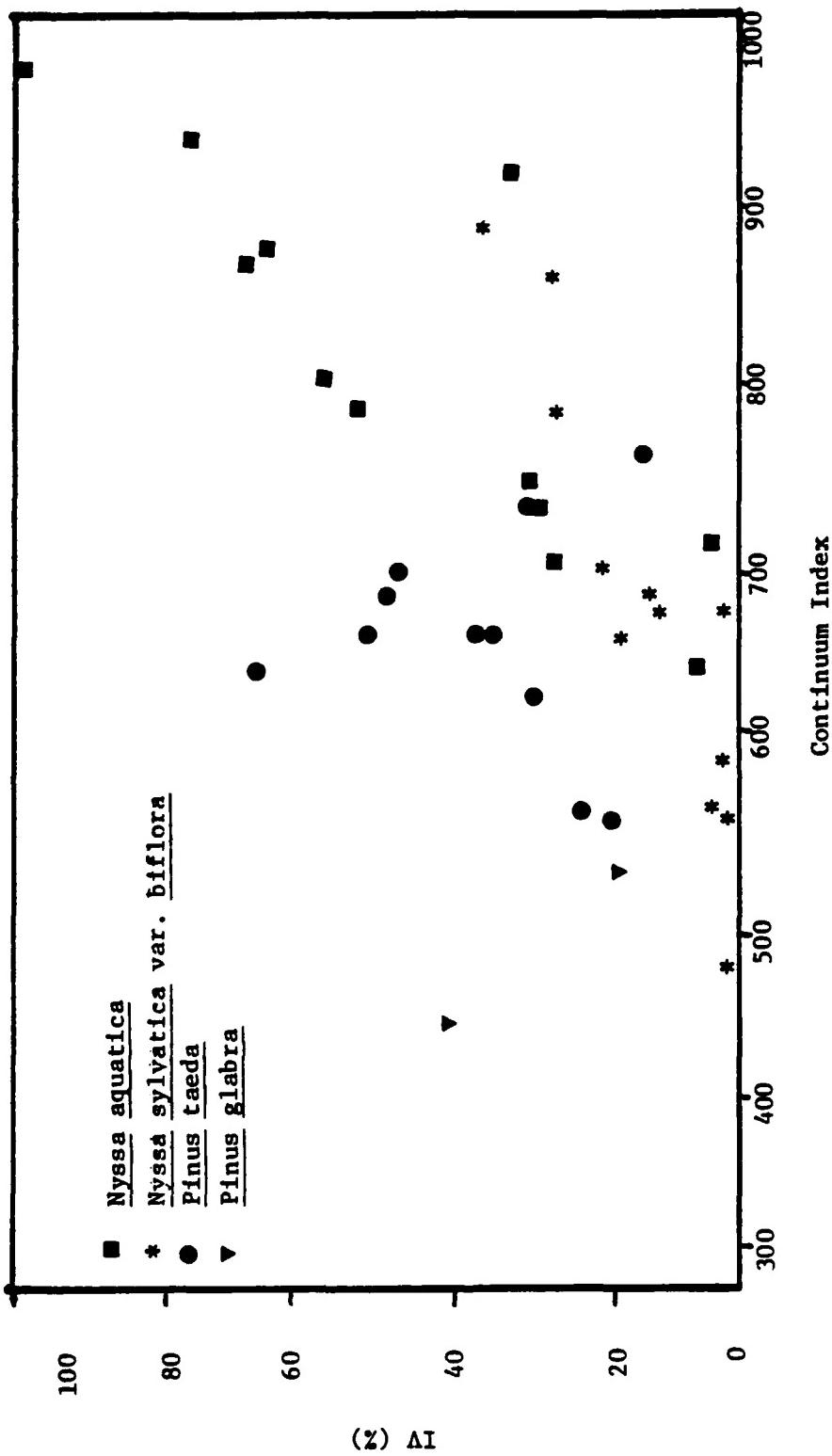


Figure 39. Importance values of four species for zones arranged in order of continuum index. Each point represents a separate stand for each species.

that species on wetland-to-upland gradients in Louisiana are distributed along a continuum and react independently to the environmental conditions.

432. Figure 40 shows normalized curves for several species calculated by taking an average of values in each 100-unit segment of the continuum, following the method of Curtis and McIntosh (1951). Each of the curves shown approximates a normal curve. Fit of curve depends largely on the number of data points for the curve. Some species tend to exhibit narrow, steep curves. Such patterns indicate species which have a narrow range of tolerances and are restricted to a narrow range of conditions. Such species tend to be better indicator species than species with broad, flat curves (*L. styraciflua* in Figure 40).

#### Effectiveness of Vegetation Parameters and Criteria in Delineation Studies

433. Several community- and species-based parameters have been presented and evaluated for utility in delineation studies. The evaluation examined the parameters' ability to demonstrate patterns along the transects of each site, and the ability of various criteria for use with these parameters to consistently identify boundaries or incongruities in pattern. At this point, it is worthwhile to review the advantages and disadvantages of each method.

#### Abundance parameters

434. Abundance patterns based on total density, cover, and basal area depend on the characteristics of each zone and vary as species respond to different environmental conditions. A major disadvantage of these parameters is that the patterns may be affected by conditions such as age of stand and successional status, which are not directly related to wetland-upland gradients. Furthermore, different strata can respond simultaneously

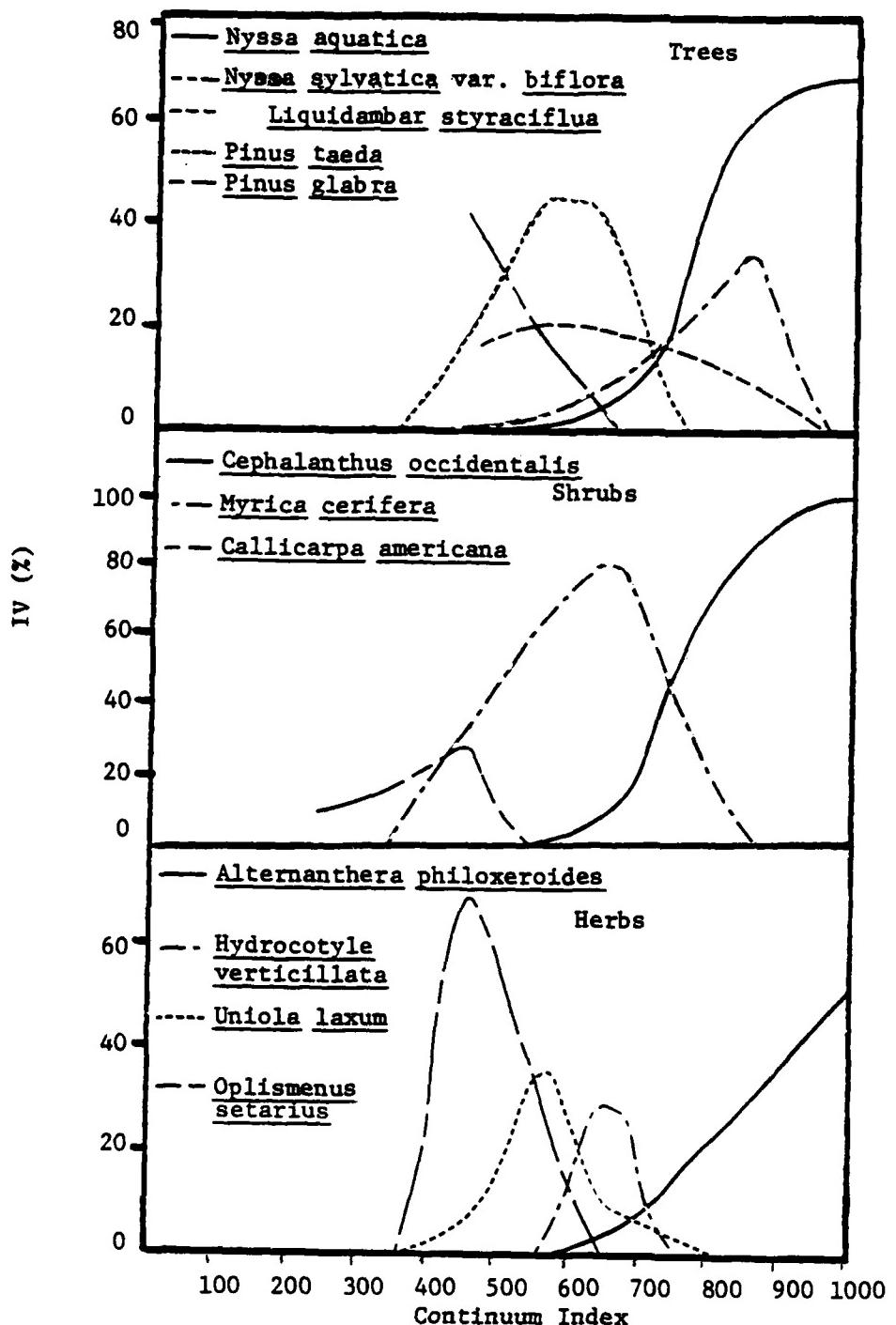


Figure 40. Importance value curves for abundant species in six Phase II sites. Data smoothed out by averaging values in 100-unit intervals.

to different sets of conditions. For example, on the gradient from herb-dominated wetlands to upland forests, the increasing abundance of trees causes increased shading which results in a secondary gradient influencing shrub and herb abundances, which does not influence overstory abundance. These factors make definition of regionally common patterns difficult and establishment of regionally consistent criteria almost impossible.

#### Species richness and diversity

435. Table 33 indicates that on an average basis for the region, species richness would appear to increase along gradients from herb- and shrub-dominated communities to forested communities. On site-specific analysis, however, such patterns were not apparent. In most sites, there was no significant trend. Paradoxically, the larger changes encountered were along forest-to-forest gradients, as in Site B2 where successional status and disturbance affected the species composition more than did the hydric gradient.

436. Like the other community-based parameters, species richness is quickly calculated and depends on minimal field data collection and can be performed by personnel with a low level of expertise.

#### Similarity Indices

437. In almost all cases, similarity indices exhibited patterns consistent with presumed zonation along wetland-to-upland gradients. Patterns among qualitative and quantitative parameters were very close. In most cases, use of a 1:1 ratio for midpoint and 70-percent to 80-percent threshold values for boundaries gave reasonable approximations of transition zones if results from all strata were averaged. Site B2 was an instance where this method yielded poor results.

438. The basic disadvantage of this method and the reason why it failed in Site B2 is the same as that for the community-based parameters. It is because a significant change in the parameter values can result from causes other than position along the wetland-to-upland gradient.

439. For example, the mouths of the major river basins (Pearl, Mississippi, and Atchafalaya) are composed of wetlands. At the lowest ends, salt marsh occurs. Moving up the basins, wetlands may progress through brackish marsh to intermediate marsh to shrub swamp to cypress-tupelo-gum swamp to bottomland hardwood swamp without leaving the wetland. This zonation within wetlands is caused by factors such as salinity and flow rate as much as by elevation and hydroperiod. Yet, the IS values will change radically as each community type is entered. Often, the degree of similarity will drop to 0 percent within a few meters along such a transect.

440. Cultural practices also can lead to significant differences in species composition without relating to the hydric gradient. Clearing, burning, or grazing in a forest may open the area to a new group of invading species without affecting the hydric gradient.

441. Similarity indices and community parameters may be used to quantitatively document a delineation which may be related to the hydric gradient. However, the identification of the boundary and the reason for its existence are not explained by the quantitative nature of the data. Such identifications often must be subjective and are based on the interpretation and experience of the observer. In these instances, the criteria for delineation are arbitrary and site-specific.

442. The objections based on the influence of non-hydroperiod factors may be overcome if several procedures are followed:

- a. Sites must be selected carefully to reflect natural conditions and simple homogeneous gradients.
- b. Careful field notes must be kept to explain factors which may affect the species composition or growth rate.
- c. The baseline or lowest zone of comparison must be placed in the uppermost true zone or type of wetland community.
- d. The observer must be able to identify zones and community types.

443. Unfortunately, ideal field conditions are rarely encountered; the method must be usable for all sites regardless of condition. It is usually in the disturbed or complex sites that quantitative methods will be desired to solve delineation problems.

#### Indicator species groups

444. The indicator species concept is a possible means of avoiding these problems because each zone is evaluated independently and decisions are not based on the relations among zones. Any location can be classified without need to sample any other location. The method can be a strong objective tool for delineation. It also has high versatility since species groups can be defined on the basis of several parameters.

445. The disadvantages of the concept are related to the level of effort involved and to the potential for misuse. As shown in Figure 35, the classification of zones is greatly influenced by the species selected as indicator groups. The results are affected both by the number and type of species selected.

446. If species do occur as discrete aggregations or communities with similar environmental responses, it would be expected that groups of such indicator species would be easy to identify and quantify. Responses and therefore groups theoretically should be similar regardless of the parameter used to select

groups. This has not been the case with the Louisiana data, in which groups selected by different parameters rarely have more than 50 percent of species in common. These results support the continuum concept of vegetation and argue against the validity of using specific groups of species as parameters.

447. The indicator species concept often has been applied for regions with relatively small groups of species included. The validity of this method is questionable because the probability of a sufficient number of these species occurring at any one location in the region is usually low. This goes back to the principle that absence of a species is not a valid criterion for proving that it could not occur or that conditions are not suitable. Use of a small number of species in an indicator group too often puts an observer in the position of having to define an area on the invalid principle of species absence.

448. Numerous conditions can occur which may result in absence of species, conditions which are unrelated to the gradient or determination in question. This can be illustrated by an example of a wetland in which the native vegetation has been destroyed by some disturbance (i.e., drainage, impoundment, or clearing). When the disturbance is removed, the environmental conditions may revert to those which supported the native wetland vegetation. In the absence of a source of seed material, the original wetland species may not recolonize the area even though they could. Under this scenario, other species of a transitional group may continue to be present in the transitional or upland zones adjacent to the wetland. Some of these may be widely tolerant species which can survive over a range of conditions from wetland to upland. With the removal of competition from the obligative wetland species, these transitional or facultative (able to tolerate but not requiring a condition) species may invade and thrive. In a hydrological sense the area would remain a wetland, but if only a small group of indicator species were

presented as a criterion, an observer might have no indication of the fact based on species composition. There would be no criterion to distinguish it from an extremely xeric or upland site.

449. It is therefore desirable, when using indicator species groups, to compare the response of groups of different tolerances to obtain maximal information about the site. In this instance, the knowledge that upland indicator species also were absent would be valuable supplemental information.

450. Unfortunately, construction and validation of three groups of sufficient size requires a high level of effort. The initial results (Figure 35) show that resolution of agreement by all groups is difficult. Rather than attempting to perform such a resolution in this study, the use of the continuum index concept was investigated.

#### Continuum index

451. Data sources and parameters are identical for the continuum index (CI) and the species indicator groups. The continuum response is an aggregate response of all three groups of indicator species. As such, three of the variables (number of groups, number of species in groups, and list of species in groups) involved in setting criteria are eliminated. The only variable involved in setting delineation criteria for CI values is which CI value is used as a delineation criterion.

452. Like the indicator species groupings, the CI can be determined for a single zone and is not dependent on values of adjacent zones. This can be both an advantage and a disadvantage. It is a disadvantage because it requires a considerable regional data base before SAN values and CI criteria can be established. Establishment of CI criteria on a regional basis also is somewhat subjective.

453. However, once the criteria for a regional CI method are selected and approved, then delineation and classification of any zone can be made based on a totally objective treatment of quantitative data. It becomes independent of observer judgement in selecting baselines, determining boundaries, and evaluating causes of patterns.

454. Establishment of species adaptation number (SAN) values and choice of the SAN parameter (refer to Table 28 for parameters) also requires initial subjective decisions. In particular, it requires decisions on the data base to be included and the nature of the steps involved in determining SAN methods. Because of the large data base and the fact that the CI is based upon responses of all species, the effects of errors are smoothed out. As shown in Figure 36, the patterns of response are remarkably even for six different parameters. If scaled to similar slopes, all would show similar patterns for most sites. CI values also provide a check on the validity of the ranking and derivation of the SAN values. When the importance value for a species is plotted on the CI as in Figure 40, the relative positions of species can be checked.

455. Four SAN parameters were evaluated for the shrub and overstory strata. The  $SAN_u$  parameter was determined to be unsatisfactory because:

- a. The species in the wetland group were all minor in dominance.
- b. Obviously wetland species were omitted from the wetland group.
- c. Zone classifications showed poor agreement to those of the other parameters.

456. The remaining six parameters (Table 28) were used to calculate CI values for each sampling zone. Sampling zones were first divided into wetland, transitional, and upland classes on the basis of subjective field evaluations. The range of CI values thus obtained for each class showed substantial overlap. Classes were refined by reducing overlap by transferring sampling zones

among groups until overlap was minimized. The only restrictions on transfers were that classes had to remain sequential along transects and that a transfer had to result in improvement for three of the six parameters and loss of resolution in no more than two. Table 34 shows the classification of sampling zones after subjective evaluation, after ranking by tree strata, and after final ranking by shrub strata. Table 35 shows the ranges of CI thus determined for each vegetation zone. It should be noted that even after this ranking, certain areas of overlap occur. Vegetation zones in these ranges should be considered as boundary or tension zones.

457. The six parameters (refer to Table 28 for definition of parameters) were rated on the basis of the number of zones which each misclassified compared to the final classification, the degree of overlap of CI values among classifications, and the accuracy in depicting patterns within sites. For both tree and shrub strata, the  $CI_u$  (continuum index values based on upland SAN values) parameters consistently ranked in the bottom third. Overall  $CI_w$  and  $CI_c$  parameters were similar, but average rankings showed  $CI_{w-qn}$  first, followed by  $CI_{c-qn}$ ,  $CI_{w-ql}$ , and  $CI_{c-ql}$ . Calculation of CI for herbs was done using only the  $CI_{w-qn}$  parameter.

458. The continuum index was the only method by which delineation criteria could be readily defined in a manner consistent among all sites and strata. Several of the other parameters could define trends or patterns which accurately portrayed the sites but upon which criteria could not be effectively defined for all sites. Further evaluation of these parameters may eventually produce criteria. Figure 41 shows mean values for some indicator species groups plotted along the CI. It appears that these groups do respond similarly to individual species and that they also fairly represent positions along the gradient which are consistent with the delineations produced by the continuum index concept.

Table 34  
Preliminary and Final Classifications of  
Zones at Six Phase II Sites

Site	Sampling Zone	Initial	Classification	Final Classification
		Subjective Classification	Following Overstory Ranking	Following Shrub Ranking
A1	1	W	W	W
	2	T	T	T
	3	U	U	U
A2	1	W	W	W
	2	W	W	W
	3	T	T	T
	4	U	T	U
	5	U	U	U
B1	1	W	T	T
	2	W	T	T
	3	T	U	T
	4	T	U	T
	5	U	U	T
	6	U	U	U
B2	1	W	W	W
	2	W	T	T
	3	T	T	U
	4	T	U	U
	5	U	U	U
	6	U	U	U
	7	U	U	U

(Continued)

Table 34 (Concluded)

<u>Site</u>	<u>Sampling Zone</u>	<u>Initial Subjective Classification</u>	<u>Classification Following Overstory Ranking</u>	<u>Final Classification Following Shrub Ranking</u>
C1	1	W	W	W
	2	W	W	T
	3	W	T	W/T
	4	W	T	W/T
	5	W	T	W/T
	6	T	T	T
	7	T	T	T
	8	U	T	T
	9	U	T	T
C2	1	W	W	W
	2	W	W	W
	3	W	W	W
	4	W	W	W
	5	T	W	T
	6	U	U	U

Key:    W = wetland zone  
       T = transitional zone  
       U = upland zone  
       W/T = boundary zone

Source: ESE, 1981.

Table 35  
Proposed Ranges of CI Values to be Used as Tentative Criteria  
for Classification of Lands in Southern Louisiana

Classification	Strata		
	Overstory	Shrub	Herb
Wetland Zone	773-1000	653-1000	701-1000
Wetland Border Zone	744-773	631-653	700
Transition Zone	692-744	455-631	490-699
Transition Border Zone	632-692	446-455	469-490
Upland Zone	100-632	100-446	100-469

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Source: ESE, 1981.

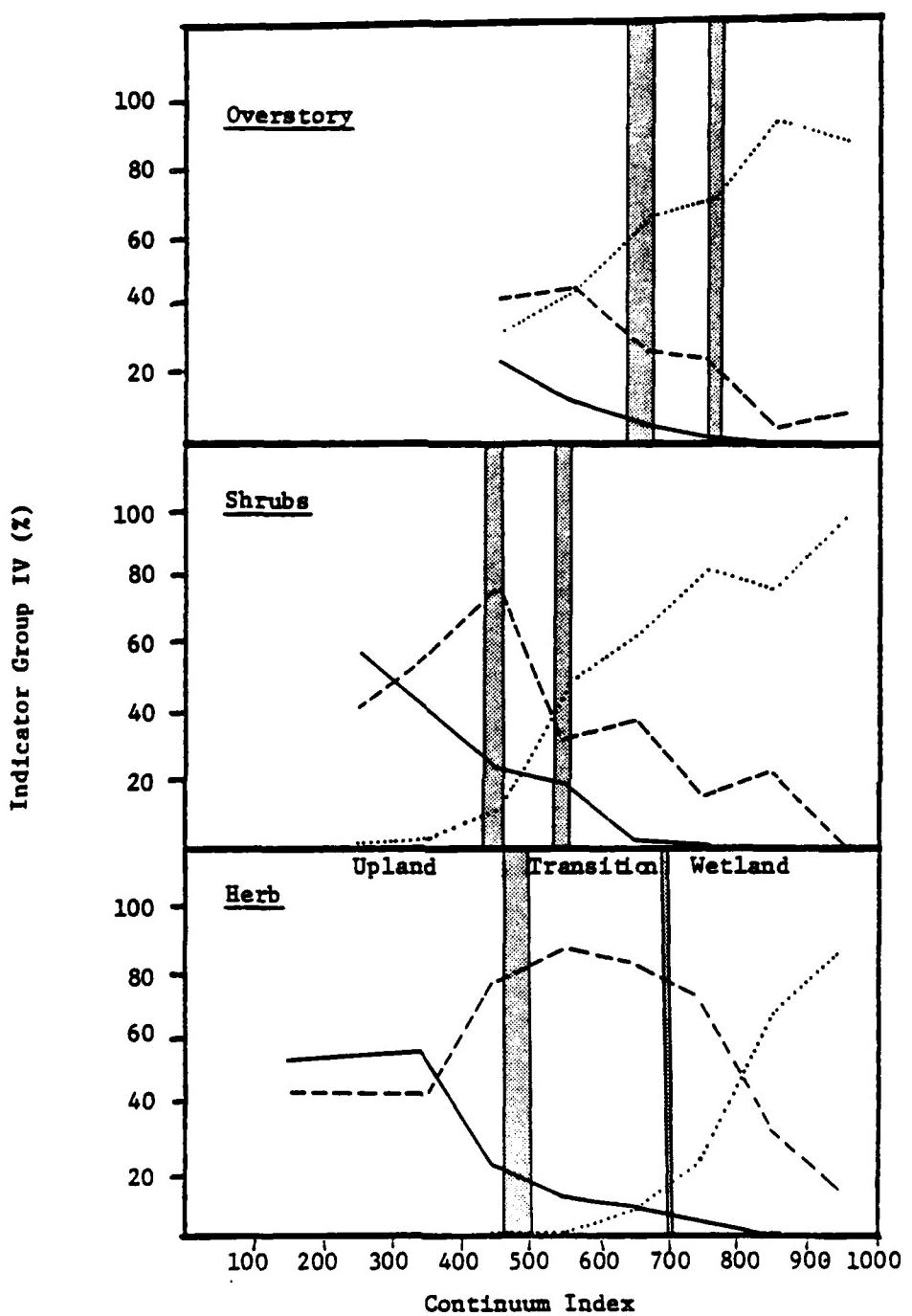


Figure 41. Dominance of indicator species groups along a continuum index. Data from six sites averaged by 100 unit intervals. Vertical bars show boundary regions among upland, transition, and wetland zones.

## PART VII: CONCLUSIONS AND RECOMMENDATIONS

### Characteristics of Louisiana Wetlands

459. Data obtained for more than 200 species and 8 separate community types allowed evaluation of absolute and relative distributions of species along wetlands transitional gradients. The results tend to supplement and support previous descriptions of community structure and composition.

460. The study did indicate that, although most stands in the region are similar in type and composition, variability among sites and patterns of zonation was great enough that criteria could not be established to delineate zones on the basis of structure.

461. In general, cypress-tupelo-gum swamps appear to have highest overstory and lowest herb densities of any community type. Bottomland hardwoods showed more structural and compositional similarity to oak-pine and mixed hardwoods uplands than to the cypress-tupelo-gum swamps. Upland and transitional communities are the most variable, partly because they are the most often and most recently disturbed.

462. Transitional zones in the region usually cover areas about 10 m to 20 m in width. Zones may be as narrow as 3 m, as in Site A1, but more often may be much larger. Few areas exist where the transitional zones occur as straight bands for more than 100 m. The longest uninterrupted zones occur along the boundaries of the coastal marsh community. Sampling strategy and selection of methods may be affected by the size and orientation of these zones.

### Suitability of Sampling Methods

463. Intensive sampling and comparisons of many methods at three Phase I sampling sites have indicated that it is possible to

obtain quantitative data on vegetation abundance and species composition which are both efficient and accurate. Phase II results verified the predictive conclusions reached in Phase I regarding sampling efficiency. The major limitation is that many sites either do not have sufficient areal extent or sufficient width of the transitional area to allow the intensity of sampling which would be needed; therefore, prediction of sampling requirements remains difficult. The following paragraphs summarize the major conclusions drawn from the Phase I and Phase II studies.

464. Under most conditions, overstory density is adequately sampled by all methods tested except the distance methods and the 200-m<sup>2</sup> circular quadrats. Due to the ease of sampling, the 100-m<sup>2</sup> circular quadrat was found to be the most efficient sampling method. For adequate basal area sampling with any method, the sampling intensity must be two to six times that of density sampling. Cover measurements generally are less accurate than density-based methods in defining the relative importance of major species, but the line-intercept modification yields generally acceptable data when used in conjunction with a density-based method.

465. For sampling of the shrub stratum, cover-based methods such as the line-intercept modification and the visual cover estimation are more efficient than density-based methods. These cover-based methods require from 33 to 50 percent less field sampling time to reach adequate sampling standards. Such standards used in this study were an SEM of 15-percent CAL and an IS<sub>BC</sub> value of over 80 percent as compared to census data. Quadrat sizes of 16 m<sup>2</sup> to 25<sup>2</sup> are most suitable for density determinations. In most cases, 1.0-m<sup>2</sup> quadrats arranged along perpendicular belt transects also yield adequate results, although total density may be overestimated. In locations where species diversity is high and density is low or where a large variation occurs, a 10-percent CAL would be required to yield the required 80-percent IS value for accuracy.

466. Density in the herbaceous stratum is best sampled by 0.125-m<sup>2</sup> quadrats in most situations. Slightly smaller quadrats may be more efficient in high-density, homogeneous marshes, and larger (0.250-m<sup>2</sup>) quadrats are more efficient and accurate in areas of very sparse vegetation. Line-intercept and visual cover estimation techniques also give adequate efficiency and accuracy under most conditions. Belt transects utilizing 0.125-m<sup>2</sup> units, the line-intercept modification, and the visual cover estimate techniques should all result in 80-percent IS<sub>BC</sub> accuracy values when total stand density or cover is sampled to the 10-percent SEM level of effort.

467. Phase I results indicate that the effectiveness of sampling methods in terms of both efficiency and accuracy is dependent to a large extent upon the characteristics of a site or zone. Usually, these site-specific differences consistently influence all methods for sampling of a particular stratum.

468. For all three strata, vegetation density appears to be the primary factor influencing effectiveness. When density is high, efficiency and accuracy often are high, and a lower sampling intensity will be needed. Diversity (species number) also tends to influence effectiveness, although to a lesser extent than density. Accuracy in species composition determination is particularly influenced by diversity, and tends to decline as diversity increases.

469. A third factor which was not specifically evaluated is the amount of variability within a zone. This factor is particularly important in transition zones where two distinct and homogeneous types meet, such as when a brackish marsh grades into an oak-pine upland forest. In such zones, quadrats in which there are no individuals may be located directly adjacent to quadrats with hundreds of individuals (e.g., marsh grass culms). Such zones have extremely high variability for all strata and require high levels of sampling effort.

470. One means of artificially reducing the variability of the data obtained in such zones without increasing field sampling effort is to make use of a logarithmic transformation ( $x = \log_{10} x + 1$ ). When using a log transformation, the  $\log_{10}$  value of the actual data number plus 1 is used instead of the raw number. For example, the  $\log_{10} x + 1$  values for 0, 1, 10, and 100 are 0.0, 0.7, 2.4, and 4.6, respectively. Log transformation using these numbers would reduce variability by reducing the range of values from 100 units (0-100) to 4.6 units (0-4.6). Although additional computation time would be required, such transformations can be programmed into many computer or programmable calculator routines.

471. Table 36 summarizes the overall effectiveness of sampling various strata under the range of conditions commonly found in the study area. The most effective strata for quantitatively indicating vegetative characteristics within each zone can be estimated from this table.

472. Along a gradient among zones or from one dominant stratum to another, a single stratum may not be continually effective. Under such conditions, it is recommended that the sampling plan include sampling of at least two strata. These strata should be selected to give the highest possible effectiveness over the range of zones or community types found along the gradient. The herbaceous and overstory strata generally will combine to form the most effective combination.

473. It is recommended that sampling along transitional gradients be done along transects perpendicular to the contours. When sufficient area is available, the transects should be placed on a stratified random basis.

474. For overstory sampling, it is recommended that nonoverlapping, but contiguous 100-m<sup>2</sup> circular quadrats be employed along the transect for recording density and, if desired, basal area. The distance meter/variable radius technique is

**Table 36**  
**Effectiveness of Quantitative Sampling for Specific Strata in**  
**Combinations of Zone and Dominant Strata**

Strata to be Sampled	Parameter	Zone and Dominant Strata					
		Wetland			Transition		
		Tree	Shrub	Herb	Tree	Shrub	Herb
Tree	Efficiency	High	NA*	NA	Moderate	NA	--**
	Accuracy	High	NA	NA	Moderate	NA	High
Shrub	Efficiency	Low	Low	Moderate	Moderate	Low	Low
	Accuracy	Moderate	Moderate	Moderate	Moderate	Low	Moderate
Herb	Efficiency	Low	High	High	Moderate	Moderate	Moderate
	Accuracy	Low	Moderate	High	Moderate	Moderate	Moderate

\* NA = Not appropriate--very low.

\*\* Zone not sampled.

Source: ESE, 1981.

recommended for greatest efficiency. The line-intercept modification should be employed along each transect to supplement the density data. When possible, 0.5-m units are recommended to provide a more accurate estimate of absolute cover, although 1.0-m units will suffice for relative cover determinations.

475. For shrub sampling, belt transects using contiguous  $1.00\text{-m}^2$  quadrats are preferable for density determinations in most conditions. The line-intercept modification can be used in conjunction along the transect line for cover evaluations. When an accurate estimate of absolute density and cover is required, the quadrat size should be increased to  $16\text{ m}^2$  and cover should be estimated visually within the quadrat. However, this modification may obscure differences in species composition along the gradient.

476. For sampling of herbaceous vegetation, a combination of the line-intercept modification for cover and a belt-transect using  $0.125\text{-m}^2$  ( $0.25\text{-m} \times 0.50\text{-m}$ ) units for density is recommended for most areas. In cases where herbaceous cover is sparse, larger quadrats ( $0.25\text{-m}^2$ ) are recommended.

477. A recommended sampling plan for sampling all strata is presented in Figure 6. When total density and cover are sampled to an SEM of 15 percent for trees and 10 percent for shrubs and herbs, the resultant community description for species composition within a zone should be within 80 percent of the true composition as expressed on the ISBC.

478. Figure 6 illustrates a recommended method for initiating the sampling plan at a site containing a transition zone. The method is similar to that used in Phase I of this study, in which the approximate upper and lower ends of the transition zone are qualitatively located. The midpoint of these limits is connected (Figure 6A) to form the initial axis of the sampling area. A baseline is identified within the wetland zone and

parallel to the initial axis (Figure 6B). The baseline is then divided into equal segments and transects are located randomly within segments, running perpendicularly from the baseline to the upland zone (Figure 6C).

Use of Vegetative Criteria for Delineating  
Wetlands Transition Zones

479. Several parameters and criteria were evaluated for their value as delineation criteria, including total abundance patterns, species diversity, species compositional trends, indicator species groups, and continuum indices. Abundance and species composition were found to yield distinct patterns across sampling zones, but the patterns were not consistent among sites, even among those with similar physiognomic features. It was impossible to assign delineation criteria applicable to all sites. The divergence in patterns is related to the influence of factors such as successional state, degree of clearing, and impoundment, which impose secondary patterns. Species diversity and richness remained unchanged over many of the sites, although the communities have rather distinct ranges on a regional basis.

480. Because there are patterns among zones, including sharp discontinuities when a change in vegetation occurs, many of the methods can be used to help document a delineation decision. The quantitative methods can be used to demonstrate that some type of change has occurred, but the nature of that change is an interpretation made by the observer using his judgement. It therefore remains based on the experience, expertise, degree of judgement, and qualifications of the observer.

481. If the abundance or similarity index methods are selected for use, it is recommended that data for all of the parameters be collected and presented, because a single parameter may yield an erroneous interpretation. Evaluation of several parameters will maximize information for decisions and will allow

double-checking of interpretations. It is also recommended that a detailed description of the site and communities be presented to a reviewer to prevent misuse or misinterpretation.

482. A definition of indicator species groups based on objective, consistent criteria was attempted, with several variations of parameters based on species wetland-to-upland ranges. The groups thus defined were found to be inconsistent and inconclusive. The choice of parameter affected species within groups and led to wide differences in results.

483. The facts indicate that delineations made by this method can be skewed or manipulated to yield whatever results are desired, and can lead to misuse or misinterpretation. This ability for groups and resulting patterns to be manipulated may, however, be used to advantage to refine criteria and groups to best represent the true situation. Due to the extensive effort necessary for such manipulations and the need for increased data on many species, refinement of groups was not attempted in this study.

484. One reason that indicator species groups may be ineffectual in delineation of zones is that every species indicates something slightly different. Species appear to occur along a continuum and to respond independently and individually to a set of factors. Therefore, indicator assemblages may be an artificial concept which would be valid only if large numbers of species are included.

485. The continuum index concept described by Curtis and McIntosh (1951) is based on the recognition that species are distributed independently along gradients. This concept has been applied to the wetland-to-upland gradient in Louisiana and has been found to indicate distinct patterns within sites which are consistent with the subjective interpretation of patterns among zones. The method was found to yield consistent patterns

regardless of the effects of disturbance, successional state, or other influence.

486. The continuum index and indicator species concepts can both use SAN values as a data base, on which to make decisions concerning criteria or definitions of wetland-transition-upland groups. The methods differ, however, in that the indicator species concept requires a separate decision on each individual species. Each of these separate decisions should be based on a data base containing several observations or pieces of information. If a species is found only rarely, then the data base will often be inadequate for a decision. The indicator species concept, unless every species is defined, will often require invalid decisions made on absence of species.

487. Because the continuum index method measures an integrated approach and classification decisions are made on a single integrated parameter (CI), the importance of the SAN value of a single species is lessened; decisions with the same level of confidence can be made on a smaller data base. Values for species not previously included can be calculated on a site-specific basis with less chance of biasing the result. Finally, compilation of a complete and adequate regional data base would require less effort and fewer subjective decisions than would the same process for indicator species.

488. On the basis of results at six sites, provisional CI ranges have been proposed as potentially useful for delineating wetland, transition, and upland zones in Louisiana. These ranges were found to allow consistent interpretations among results from three vegetation strata.

#### Further Research Needs and Recommendations

489. Four areas of further research have been identified as providing additional useful information:

- a. It is recommended that the continuum index concept be more fully tested as a tool for delineation in the southern Louisiana region. An evaluation would involve collecting a larger data base including more species and more observations on most species in order to assign regionally acceptable SAN values.

It is recommended that one means of collecting the data include using data from the many studies already existing for the region. Tests of association or association analysis techniques may be used to determine the affinity of additional species to those already ranked; values for additional species would be assigned on the basis of degree of association to known species.

It is recommended that additional sites then be sampled and CI values calculated. Subjective evaluations as to the classification of each area would be used to refine the CI ranges provisionally proposed.

An overview committee including experts and representatives of each organization performing delineations is proposed as a body to ensure that objective decisions acceptable to all are made. The committee should review methods and existing data to be used, sites to be sampled, and SAN values assigned. The committee should reach consensus decisions concerning the subjective classification of each area.

- b. The CI concept has been recommended partly because of its simplicity; its readily understandable, 2-dimensional presentation; and the fact that it represents integrated vegetation response. Further understanding of forces acting on this response would provide additional documentation supporting the concept and describing the validity of the vegetational patterns in the region.

It is recommended that additional data on the physical parameters of the sites be collected and correlated to vegetational response through ordination or factor analysis techniques. Parameters relating to elevation, hydroperiod, soil type, soil moisture, and salinity should be examined.

- c. If site-specific methods (i.e., similarity indices) are used in lieu of the regional criteria (CI) approach, appropriate statistical tests should be

applied to test for significant differences among zones. Such tests may include ANOVA, student's T-test, the Mann-Whitney U-test (Sokol and Rohlf, 1973), or Monte Carlo simulations (Ricklefs and Law, 1980), as appropriate.

- d. In many sites, variability among replicates may be so large that it may not be possible to sufficiently reduce standard errors due to physical spatial limitations; especially in transition zones where data may include a few large numbers interspersed with many zero values. It is recommended that the use of various transformations, including the logarithmic transformation, be evaluated for reducing variability and the amount of sampling replication needed.

490. The use of quantitative methods for producing a standardized, objective, regional means of performing wetland and transition zone delineations does appear to be a feasible and attainable goal. However, substantial amounts of research remain to be done before this goal is reached.

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## APPENDIX A

Table A-1

List of Species Found in Study Sites\*

Species	Common Name	Sites
<u>Agrimonia rostellata</u> Wallroth	Agrimony	A2
<u>Alternanthera philoxeroides</u> (Martius) Grisebach	Alligator weed	B2, A1, C1, A2, C, A
<u>Castanea dentata</u> (Marshall) Borkh.	American chestnut	B
<u>Ulmus americana</u> L.	American elm	B2
<u>Peltandra virginica</u> (L.) Kunth.	Arrow arum	C1
<u>Sagittaria latifolia</u> Willd.	Arrowhead	C1
<u>Viburnum dentatum</u> L.	Arrow-wood	B
<u>Paspalum notatum</u> var. <u>saurae</u> Parodi	Bahia grass	B2
<u>Taxodium distichum</u> (L.) Richard	Bald cypress	B, B2, A1
<u>Smilax laurifolia</u> L.	Bamboo	A, C2
<u>Tilia americana</u> L.	Basswood	A2
<u>Callicarpa americana</u> L.	Beauty berry	B, C2, B2, A1, B1, A2
<u>Galium pilosum</u> Aiton	Bedstraw	B1, A
<u>Fagus grandifolia</u> Ehrhart	Beech	B, B2, A1, B1
<u>Aristolochia serpentaria</u> L.	Birthwort	B2
<u>Carya cordiformis</u> (Wang.) K. Koch	Bitternut hickory	A, C, B, A2
<u>Rubus argutus</u> Link	Blackberry	B2, C2
<u>Rubus betulifolius</u> Small	Blackberry	A, C, B1, C1
<u>Rubus trivialis</u> Michx.	Blackberry	A2
<u>Nyssa sylvatica</u> var. <u>biflora</u> (Walter) Sargent	Black gum	A, B, B1, C1, A2
<u>Robinia pseudoacacia</u> L.	Black locust	B2
<u>Juncus romerianus</u> (Scheele)	Black needlerush	A1, A
<u>Juglans nigra</u> L.	Black walnut	C
<u>Salix nigra</u> Marshall	Black willow	C, C2, C1, A2
<u>Dicentra cucullaria</u> (L.) Bernh.	Bleeding heart	B2, A2
<u>Trichostema dichotomum</u> L.	Blue curls	B2
<u>Sabal minor</u> (Jacquin) Persoon	Blue palm	A, C, C1, A1
<u>Bumelia lycioides</u> (L.) Persoon	Buckthorn	B
<u>Magnolia grandiflora</u> L.	Bull bay	B, A1, B1, A2
<u>Sagittaria falcata</u> Pursh	Bulltongue	A1, C, C1
<u>Scirpus olneyi</u> Gray	Bulrush	A1
<u>Clitoria mariana</u> L.	Butterfly pea	C1, C
<u>Cephalanthus occidentalis</u> L.	Button bush	B, C2, B2, C1, A2
<u>Eryngium yuccifolium</u> Michaux	Button snakeroot	C
<u>Arundinaria gigantea</u> (Walter) Muhl.	Cane	B2, B1, A2, B
<u>Lobelia cardinalis</u> L.	Cardinal flower	A2
<u>Fraxinus caroliniana</u> Miller	Carolina ash	A2, B2, C2, B
<u>Prunus caroliniana</u> Aiton	Carolina laurel cherry	B
<u>Axonopus affinis</u> Chase	Carpet grass	B2

(Continued)

\* Includes species appearing in quantitative samples (Appendices B and C), and also those species which were observed but did not fall within sampling areas. (Sheet 1 of 5)

Table A-1 (Continued)

Species	Common Name	Sites
<i>Mollugo verticillata</i> L.	Carpet weed	C
<i>Sapium sebiferum</i> (L.) Roxb.	Chinese tallowtree	C, B2, C1
<i>Mikania scandens</i> (L.) Willd.	Climbing hempweed	C1, C2, C2
<i>Centella asiatica</i> (L.) Urban	Coinwort	B2, A
<i>Echinodorus cordifolius</i> (L.) Grisebach.	Creeping water plantain	A2
<i>Anisostichus capreolata</i> (L.) Bureau	Cross vine	A1, B, A2, A, B1, C2
<i>Gnaphalium obtusifolium</i> L.	Cudweed	B2
<i>Leersia virginica</i> Willd.	Cut grass	A2, C2
<i>Convolvulus virginica</i> L.	Dayflower	C1
<i>Rumex</i> sp.	Dock	C
<i>Sporobolus</i> sp.	Dropseed	C1
<i>Lemna minor</i> L.	Duckweed	C2, C1, A2, B
<i>Asplenium platyneuron</i> (L.) Oakes	Ebony spleenwort	A2
<i>Sambucus canadensis</i> L.	Elderberry	A
<i>Elephantopus carolinianus</i> Willd.	Elephant's foot	A1, A2, B1, C2
<i>Elephantopus tomentosus</i> L.	Elephant's foot	B2, A2, B
<i>Vaccinium elliotii</i> Chapman	Elliott's blueberry	B, B2, B1
<i>Boehmeria cylindrica</i> (L.) Swartz	False nettle	A2
<i>Cabomba caroliniana</i> Gray	Fanwort	C2
<i>Lyonia lucida</i> (Lam.) K. Koch	Fetter bush	A, B
<i>Cornus florida</i> L.	Flowering dogwood	C2, A2, B2
<i>Limnobium spongia</i> (Bosc) Steudel	Frog's bit	C2, A2
<i>Vitis vulpina</i> L.	Frost grape	C2
<i>Geum</i> sp.	Geum	B
<i>Zizaniopsis miliacea</i> (Michx.) Doell & Aschers	Giant cutgrass	A1
<i>Solidago rugosa</i> Miller	Goldenrod	B2, C2
<i>Vaccinium stamineum</i> L.	Gooseberry	B, B2
<i>Gramineae</i> sp. 1	Grass	B, B1, B2
<i>Smilax bona-nox</i> L.	Greenbrier	A, B, B2, C1, C, A1, B1, C2
<i>Smilax pumila</i> Walter	Greenbrier	A, B, B2, C3
<i>Smilax rotundifolia</i> L.	Greenbrier	A, B, B2
<i>Baccharis halimifolia</i> L.	Groundsel tree	A, C, C1
<i>Celtis laevigata</i> Willd.	Hackberry	A, C, C2, B2, A1
<i>Crataegus crus-galli</i> L.	Hawthorn	B2, B1
<i>Aralia spinosa</i> L.	Hercules club	B
<i>Ilex opaca</i> Aiton	Holly	B, B2, B1
<i>Gleditsia triacanthos</i> L.	Honey locust	A, C, C1, A2
<i>Lonicera japonica</i> Thunberg.	Honeysuckle	B2, B1, A
<i>Ostrya virginiana</i> (Miller) K. Koch	Hop hornbeam	B, B2, B1, A2

(Continued)

(Sheet 2 of 5)

Table A-1 (Continued)

Species	Common Name	Sites
<i>Ceratophyllum demersum</i> L.	Hornwort	B
<i>Hydrophila lacustris</i> Nees.	Hydrophila	C2
<i>Iris hexagona</i> var. <i>savannarum</i> Walter	Iris	A1, C1
<i>Carpinus caroliniana</i> Walter	Ironwood	B, C2, A2, B2, A1, B1
<i>Arisaema triphyllum</i> (L.) Schott	Jack-in-the-pulpit	B1
<i>Polygonum hydropiperoides</i> Michaux	Knotweed	A1, C1, A2, C, A
<i>Brunichia cirrhosa</i> Banks ex Gaertner	Ladies' eardrops	A, C, C2, B2, B1, C1
<i>Leucothoe axillaris</i> (Lam.) D. Don	Leucothoe	B
<i>Ligustrum sinense</i> Lour.	Ligustrum	B
<i>Quercus virginiana</i> Miller	Live oak	A, C, B, C1
<i>Saururus cernuus</i> L.	Lizard's tail	C2, A1, B1, C1, A2, A
<i>Pinus taeda</i> L.	Iloblolly pine	A1, B1, C1, A, C
<i>Eragrostis</i> sp.	Lovegrass	A2
<i>Rosa bracteata</i> Wendland	Macartney rose	C
<i>Panicum hemitomon</i> Schultes	Maidencane	A
<i>Glyceria</i> sp.	Manna grass	A
<i>Iva frutescens</i> L.	Marsh elder	A, C, A1
<i>Pluchea rosea</i> Godfrey	Marsh fleabane	A1, C1
<i>Galactia volubilis</i> (L.) Britton	Milkpea	B2
<i>Eupatorium coelestinum</i> L.	Mistflower	C2, B2, A2
<i>Ipomoea lacunosa</i> L.	Morning glory	A2
<i>Ipomoea sagittata</i> Cav.	Morning glory	C, C1, A
<i>Vitis rotundifolia</i> Michaux	Muscadine	A, C2, B2, B, A1, A2, B1
<i>Woodwardia areolata</i> (L.) Moore	Netted chain-fern	B1, A2, C2
<i>Quercus nuttallii</i> E.J. Palmer	Nuttall oak	B1
<i>Oplismenus setarius</i> (Lam.) R. & S.	Oplismenus	A, B1, A2, A1, C2
<i>Quercus lyrata</i> Walter	Overcup oak	B2
<i>Panicum aciculare</i> Desvaux ex Poiret	Panic grass	B2
<i>Panicum dichotomum</i> L.	Panic grass	B2
<i>Panicum scoparium</i> Lam.	Panic grass	B, B1, A, A1
<i>Panicum</i> sp.	Panic grass	A1, C2, A, B
<i>Mitchella repens</i> L.	Partridge berry	C2, B2, B1, A2, B
<i>Passiflora lutea</i> L.	Passion flower	B1
<i>Carya illinoiensis</i> (Wang) K. Koch	Pecan	A2
<i>Hydrocotyle verticillata</i> Thunberg	Pennywort	B2, A1, C1, A
<i>Ampelopsis arborea</i> (L.) Koehne	Pepper vine	A, C, C1, A2, C2, B1
<i>Perilla frutescens</i> (L.) Britton	Perilla	B2, A2, C2
<i>Diospyros virginiana</i> L.	Persimmon	A, C, B1, C1, A2
<i>Pontederia cordata</i> L.	Pickerelweed	A1, C1
<i>Carya glabra</i> (Miller) Sweet	Pignut hickory	A, B1, B2, C1
<i>Rhus radicans</i> L.	Poison ivy	B2, B1, A2, C2

(Continued)

(Sheet 3 of 5)

Table A-1 (Continued)

Species	Common Name	Sites
<u>Phytolacca americana</u> L.	Pokeweed	B1
<u>Ilex decidua</u> Walter	Possum haw	B2
<u>Quercus stellata</u> Wang.	Post oak	C
<u>Ludwigia repens</u> Forster	Primrose willow	A, A2, C2
<u>Acanthaceae</u>		C
<u>Dauibentonia texana</u> Pierce	Rattlebox	A, Cl
<u>Sesbania exaltata</u> (Raf.) Rydberg ex A.W. Hill	Rattlebox	C
<u>Aesculus pavia</u> L.	Red buckeye	A, C
<u>Cercis canadensis</u> L.	Redbud	A2
<u>Acer rubrum</u> L.	Red maple	A, C, B, Cl, A2, C2, B2
<u>Morus rubra</u> L.	Red mulberry	B2, A2
<u>Polypodium polypodioides</u> (L.) Watt	Resurrection fern	B
<u>Phragmites australis</u>	Roseau	C, A1
<u>Hibiscus lasiocarpus</u> Cav.	Rose mallow	A, Cl
<u>Ruellia caroliniensis</u> (Walter) Steudel	Ruellia	B2
<u>Hypericum hypericoides</u> (L.) Crantz	St. Andrews cross	B2
<u>Stenotaphrum secundatum</u> (Walter) Kuntze	St. Augustine grass	C, A
<u>Hypericum walteria</u> Gmelin.	St. John's-wort	B
<u>Sacciolepsis striata</u> (L.) Nash	Sacciolepsis	A
<u>Distichlis spicata</u> (L.) Greene	Saltgrass	A
<u>Spartina patens</u> (Aiton) Muhl.	Saltmeadow cordgrass	A, C
<u>Sassafras albidum</u> (Nuttall) Nees	Sassafras	B1
<u>Sebastiania ligustrina</u> (Michaux) Muell-Arg.	Sebastiania	B
<u>Carex</u> sp.	Sedge	A1, B1
<u>Cyperaceae</u> sp. L.	Sedge	B
<u>Cyperus iria</u> L.	Sedge	A
<u>Cyperus virens</u> Michaux	Sedge	A, Cl, C
<u>Stewartia malachodendron</u> L.	Silky camellia	B1
<u>Halesia diptera</u> Ellis	Silver bell	B
<u>Oxydendron arboreum</u> (L.) DC.	Sourwood	B
<u>Botrychium biternatum</u> (Sav.) Underwood	Southern grapefern	B1, B2, A2, C2
<u>Juniperus silicicola</u> (Small) Bailey	Southern red cedar	B2, A2
<u>Quercus falcata</u> Michaux	Southern red oak	A, B2, A1, B1
<u>Vaccinium arboreum</u> Marshall	Sparkleberry	B, B2
<u>Uniola laza</u> L. BSP.	Spike grass	B2, A1, B1, A2, A
<u>Selaginella ludoviciana</u> A. Brum	Spikemoss	B1
<u>Eleocharis tuberculosa</u> (Michaux) R. & S.	Spikerush	C, A
<u>Spilanthes americana</u> (Walter) A.H. Moore	Spilanthes	A2
<u>Pinus glabra</u> Walter	Spruce pine	B, B2
<u>Styrax grandifolia</u> Aiton	Styrax	B
<u>Vitis aestivalis</u> Michaux	Summer grape	B2, A2
<u>Berchemia scandens</u> (Hill) K. Koch	Supplejack	C2, B1, B2

(Continued)

(Sheet 4 of 5)

Table A-1 (Concluded)

Species	Common Name	Sites
<i>Rhododendron viscosum</i> (L.) Torrey	Swamp azalea	B
<i>Quercus michauxii</i> Nuttall	Swamp chestnut oak	B, C2, B2, A1, B1, A2
<i>Populus heterophylla</i> L.	Swamp cottonwood	B2
<i>Forestiera acuminata</i> (Michaux) Poirer	Swamp privet	B
<i>Magnolia virginiana</i> L.	Sweet bay	B1
<i>Liquidambar styraciflua</i> L.	Sweet gum	A, C, B, Cl, A2, C2, Bl, B2, Al
<i>Symplocos tinctoria</i> (L.) L'Her.	Sweet leaf	B, B2, Bl, A2, C2
<i>Clethra alnifolia</i> L.	Sweet pepperbush	B
<i>Panicum virgatum</i> L.	Switch grass	A
<i>Scirpus olneyi</i> Grey	Three-cornered grass	C, Cl
<i>Acalypha gracilens</i> Gray	Three-seeded mercury	A2, B2
<i>Cyrilla racemiflora</i> L.	Titi	B
<i>Campsis radicans</i> (L.) Seemann	Trumpet vine	A, C, B2, Cl, Bl, C2
<i>Verbesina virginica</i> L.	Verbesina	A2, C2
<i>Verbesina walteri</i> Shimmers	Verbesina	A2
<i>Viburnum obovatum</i> Walter	Viburnum	B2
<i>Viola esculenta</i> Ell.	Violet	B2, Bl, B
<i>Parthenocissus quinquefolia</i> (L.) Planchon	Virginia creeper	Bl, A2, B
<i>Itea virginica</i> L.	Virginia willow	B
<i>Planera aquatica</i> Walter ex J.F. Gmelin	Water elm	A2
<i>Spirodela polyrhiza</i> (L.) Schleid	Water flax-seed	C2, A2, Cl
<i>Nyssa aquatica</i> L.	Water gum	B, C2, B2, Cl, A2
<i>Carya aquatica</i> (Michaux f.) Nuttall	Water hickory	A2, B2
<i>Lycopus rubellus</i> Moench.	Water horehound	A2, C, B2
<i>Eichhornia crassipes</i> (Martius) Solms	Water hyacinth	Cl
<i>Quercus nigra</i> L.	Water oak	A, C, B, B2, Al, Bl, Cl, A2, C2
<i>Justicia ovata</i> (Walter) Lindau	Water willow	Al, Bl, B2, C2
<i>Myrica cerifera</i> L.	Wax myrtle	A, C, B, Al, Cl
<i>Cuphea carthagensis</i> (Jacquin) Macbride	Waxweed	Bl
<i>Quercus alba</i> L.	White oak	B
<i>Quercus phellos</i> L.	Willow oak	B, B2
<i>Ulmus alata</i> Michaux	Winged elm	A, B, B2, Bl, A2, C2
<i>Rhus copallina</i> L.	Winged sumac	B, B2
<i>Ilex verticillata</i> (L.) Gray	Winterberry	B
<i>Hammamelis virginiana</i> L.	Witch hazel	B
Oxalis sp.	Wood sorrel	B2, A2
<i>Ilex vomitoria</i> Aiton	Yaupon	A, B, C, Bl, B2, Cl
<i>Gelsemium sempervirens</i> (L.) Aiton f.	Yellow jessamine	B, B2
<i>Hypoxis hirsuta</i> (L.) Coville	Yellow star-grass	A2, Bl, B2, C2

Source: ESE, 1981.

(Sheet 5 of 5)

## APPENDIX B

Table B-1

Overstory Composition by Zones Within Three  
Phase I Sampling Sites

Species	Importance Value Index*					
	Site A		Site C		Site B	
	Second Upland Zone	Up-land Zone	Transi- tion Zone	Up-land Zone	Transi- tion Zone	Wet land Zone
<u><i>Ulmus alata</i></u>	1.05					
<u><i>Aesculus pavia</i></u>	1.15					
<u><i>Carya glabra</i></u>	1.05					
<u><i>Diospyros virginiana</i></u>	1.98	1.34				
<u><i>Quercus falcata</i></u>	3.81	0.92				
<u><i>Celtis laevigata</i></u>	5.03	0.89				
<u><i>Gleditsia triacanthos</i></u>	2.30				3.02	3.54
<u><i>Liquidambar styraciflua</i></u>	19.30	20.29			3.86	
<u><i>Carya cordiformis</i></u>	8.00	1.93	18.81	3.04	10.20	2.37
<u><i>Quercus virginiana</i></u>	7.53	10.57	8.18		8.37	0.55
<u><i>Ilex vomitoria</i></u>	29.16	16.16				16.75
<u><i>Quercus nigra</i></u>	18.67	7.88				1.56
<u><i>Pinus taeda</i></u>	22.19	36.35	54.62	42.17		
<u><i>Baccharis halimifolia</i></u>	0.89				8.91	
<u><i>Myrica cerifera</i></u>	13.01	14.05			3.54	
<u><i>Acer rubrum var. drummondii</i></u>	0.99	3.81	6.29	3.00	3.69	0.74
<u><i>Daubentonias texana</i></u>			3.27			
<u><i>Nyssa sylvatica</i> var. <u><i>biflora</i></u></u>			6.90			
<u><i>Sapum sebiferum</i></u>				15.49	9.16	5.37
<u><i>Salix nigra</i></u>				6.87		
<u><i>Vaccinium stamineum</i></u>					1.27	15.96
<u><i>Castanea dentata</i></u>					0.58	
					0.53	

(Continued)

\* Importance value basis of 100% • IV = Relative Density + Relative Cover + Relative Dominance.

Based on census values.

Table B-1 (Concluded)

Species	Importance Value Index*					
	Site A		Site C		Site B	
	Second Upland Zone	Transi- tion Zone	Upland Zone	Transi- tion Zone	Upland Zone	Wetland Zone
<i>Hamamelis virginiana</i>					1.08	
<i>Pinus glabra</i>					20.89	18.00
<i>Symplocos tinctoria</i>					10.63	6.83
<i>Vaccinium arboreum</i>					7.66	7.01
<i>Oxydendron arboreum</i>					3.83	0.51
<i>Ostrya virginiana</i>					4.42	1.76
<i>Ilex opaca</i>					0.92	2.02
<i>Quercus alba</i>					0.78	
<i>Quercus phellos</i>					27.24	12.02
<i>Nyssa aquatica</i>					9.88	0.47
<i>Quercus michauxii</i>					33.91	
<i>Rhododendron viscosum</i>					0.71	
<i>Fagus grandifolia</i>					0.48	
<i>Rhus copallina</i>					0.73	
<i>Magnolia grandiflora</i>					0.67	
<i>Ilex verticillata</i>					0.91	
<i>Taxodium distichum</i>					1.25	0.46
<i>Cyrilla racemiflora</i>					0.49	5.06
<i>Fraxinus caroliniana</i>					1.47	6.91
<i>Cephaelanthus occidentalis</i>					0.50	7.53
					6.74	

\* Importance value basis of 100% · IV = Relative Density + Relative Cover + Relative Dominance.

Based on census values.

Source: ESR, 1981.

**Table B-2**  
**Shrub Stratum Composition by Zones Within**  
**Three Phase I Sampling Sites**

Species	Importance Value*					
	Site A		Site C		Site B	
	Second Upland Zone	Upland Zone	Transi- tion Zone	Upland Zone	Wetland Zone	Upland Zone
<i>Hibiscus lasiocarpus</i>	0.22	2.88	--	--	--	--
<i>Smilax pumila</i>	1.07	--	--	--	0.40	--
<i>Quercus nigra</i>	0.22	--	--	6.70	--	1.65
<i>Rubus betulifolius</i>	2.66	--	--	4.45	--	2.45
<i>Aesculus pavia</i>	0.59	1.38	--	0.45	--	--
<i>Acer rubrum</i> var. <i>drummondii</i>	0.05	--	6.73	0.45	--	--
<i>Diospyros virginiana</i>	0.44	0.55	--	4.40	0.55	--
<i>Celtis laevigata</i>	0.98	0.20	--	0.37	4.30	--
<i>Brunnichia cirrhosa</i>	27.19	30.29	21.07	11.55	2.25	--
<i>Campsipus radicans</i>	1.13	1.20	1.16	5.60	0.30	--
<i>Ampelopsis arborea</i>	0.89	4.97	2.99	0.95	0.85	--
<i>Baccharis halimifolia</i>	0.73	2.27	20.51	1.85	13.35	45.70
<i>Sabal minor</i>	1.89	2.83	7.31	8.45	21.95	12.05
<i>Ilex vomitoria</i>	61.30	29.17	1.86	3.70	0.85	--
<i>Smilax bona-nox</i>	0.98	2.23	0.23	--	--	0.25
<i>Gleditsia triacanthos</i>	--	0.62	--	0.45	--	0.15
<i>Liquidambar styraciflua</i>	--	2.51	--	0.45	--	--
<i>Vitis rotundifolia</i>	--	0.79	0.35	--	--	--

(Continued)

\* Importance Value (IV) = Relative Density + Relative Cover. Density is based on results from randomly placed 4-m x 4-m quadrats and cover values from line-intersect results. Percentages based on 100 percent.

(Sheet 1 of 4)

Table B-2 (Continued)

Species	Importance Value*						Site B		
	Second Upland Zone	Upland Zone	Transi- tion Zone	Upland Zone	Wetland Zone	Transi- tion Zone	Upland Zone	Wetland Zone	Transi- tion Zone
<i>Iva frutescens</i>	--	3.70	4.60	4.75	40.00	37.10	--	--	--
<i>Myrica cerifera</i>	--	14.44	23.46	--	3.00	3.20	0.25	--	--
<i>Daubentonia texana</i>	--		8.40	--		--		--	--
<i>Lyonia lucida</i>	--		0.42	--				0.70	--
<i>Smilax rotundifolia</i>	--		0.93	--				0.20	1.20
<i>Quercus stellata</i>	--		--	3.25	--			--	--
<i>Sapium sebiferum</i>	--		--	13.55	4.45	--		--	--
<i>Carya cordiformis</i>	--		--	4.00	0.55	--		--	--
<i>Rosa bracteata</i>	--		--	29.30	2.95	2.00	--	--	--
Unknown shrub	--		--	--	0.55	--		--	--
<i>Ulmus alata</i>	--		--	--	--		1.60	--	--
<i>Sebastiana ligustrina</i>	--		--	--	--		0.80	--	--
<i>Aralia spinosa</i>	--		--	--	--		0.50	--	--
<i>Pinus glabra</i>	--		--	--	--		6.40	0.60	--
<i>Symplocos tinctoria</i>	--		--	--	--		22.95	11.75	--
<i>Viburnum dentatum</i>	--		--	--	--		9.70	9.95	--
<i>Vaccinium arboreum</i>	--		--	--	--		7.70	7.40	--
<i>Vaccinium ellottii</i>	--		--	--	--		6.35	8.70	--
<i>Vaccinium stamineum</i>	--		--	--	--		5.65	7.60	--
<i>Forestiera acuminata</i>	--		--	--	--		0.50	1.75	--
<i>Styrax grandifolia</i>	--		--	--	--		0.50	0.75	--

(Continued)

\* Importance Value (IV) = Relative Density + Relative Cover. Density is based on results from randomly placed 4-m x 4-m quadrats and cover values from line-intersect results. Percentages based on 100 percent.

(Sheet 2 of 4)

Table B-2 (Continued)

Species	Importance Value*						Site B		
	Second Upland Zone	Up-land Zone	Transi- tion Zone	Up-land Zone	Wet land Zone	Up-land Zone	Wet land Zone	Transi- tion Zone	
<i>Ostrya virginiana</i>	--	--	--	--	--	--	0.50	0.75	--
<i>Quercus virginiana</i>	--	--	--	--	--	3.60	2.40	--	
<i>Carpinus caroliniana</i>	--	--	--	--	--	2.10	0.50	--	
<i>Ilex opaca</i>	--	--	--	--	--	1.85	1.20	--	
<i>Oxydendron arboreum</i>	--	--	--	--	--	1.25	3.15	--	
<i>Castanea dentata</i>	--	--	--	--	--	0.95	0.25	--	
<i>Gelsemium sempervirens</i>	--	--	--	--	--	0.40	0.05	--	
<i>Rhododendron viscosum</i>	--	--	--	--	--	0.25	5.80	--	
<i>Prunus caroliniana</i>	--	--	--	--	--	0.25	1.00	--	
<i>Itea virginica</i>	--	--	--	--	--	5.13	2.25	0.75	
<i>Nyssa sylvatica</i> var. <i>biflora</i>	--	--	--	--	--	0.25	--	0.25	
<i>Cyrilla racemiflora</i>	--	--	--	--	--	0.25	8.75	7.35	
<i>Ilex verticillata</i>	--	--	--	--	--	13.55	54.95	--	
<i>Leucothoe axillaris</i>	--	--	--	--	--	2.75	4.95	--	
<i>Clethra alnifolia</i>	--	--	--	--	--	1.65	0.25	--	
<i>Hamamelis virginiana</i>	--	--	--	--	--	0.50	--	--	
<i>Magnolia grandiflora</i>	--	--	--	--	--	0.25	--	--	
<i>Callicarpa americana</i>	--	--	--	--	--	0.20	--	--	
<i>Quercus michauxii</i>	--	--	--	--	--	0.05	--	--	
<i>Cephalanthus occidentalis</i>	--	--	--	--	--	--	12.70	--	

(Continued)

\* Importance Value (IV) =  $\frac{\text{Relative Density} + \text{Relative Cover}}{2}$ . Density is based on results from randomly placed 4-m x 4-m quadrats and cover values from line-intersect results. Percentages based on 100 percent.

(Sheet 3 of 4)

Table B-2 (Concluded)

Species	Importance Value*					
	Site A		Site C		Site B	
Second Upland Zone	Upland Zone	Transi- tion Zone	Upland Zone	Wetland Zone	Upland Zone	Transi- tion Zone
<i>Fraxinus caroliniana</i>	--	--	--	--	--	--
<i>Nyssa aquatica</i>	--	--	--	--	--	--
<i>Taxodium distichum</i>	--	--	--	--	--	--

\* Importance Value (IV) =  $\frac{\text{Relative Density} + \text{Relative Cover}}{2}$ . Density is based on results from randomly placed 4-m x 4-m quadrats and cover values from line-intersect results. Percentages based on 100 percent.

(Sheet 4 of 4)

Source: ESE, 1981.

APPENDIX C  
Table C-1

Species Composition by Zone at Site A1, Shown as Importance Value

Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
	0-9m	10-19m	20-29m	30-39m	40-49m	50-59m	60-69m	70-79m	80-89m
<b>Overstory Stratum</b>									
<i>Taxodium distichum</i>	62.7	9.6							
<i>Nyssa sylvatica</i> var. <i>biflora</i>	34.3	25.7							
<i>Pinus taeda</i>	0.5	12.9							
<i>Liquidambar styraciflua</i>	2.6	8.9							
<i>Diospyros virginiana</i>		2.9							
<i>Fagus grandifolia</i>		4.6							
<i>Carrinhus caroliniana</i>		28.4							
<i>Quercus falcata</i>		2.0							
<i>Magnolia grandiflora</i>		2.0							
<i>Vitis rotundifolia</i>		1.9							
<i>Quercus michauxii</i>		1.1							
<i>Carya glabra</i>									
<i>Halesia diptera</i>									
<i>Aesculus pavia</i>									
<i>Quercus nigra</i>									
<b>Shrub Stratum</b>									
<i>Iva frutescens</i>	100.0								
<i>Myrica cerifera</i>		12.5							
<i>Pinus taeda</i>		46.5							
<i>Vitis rotundifolia</i>		41.0							

C1

(Continued)

Table C-1 (Concluded)

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Herbaceous Stratum</b>									
<i>Saururus cernuus</i>	0.7								
<i>Scirpus</i> sp.	0.3								
<i>Iva frutescens</i>	0.1								
<i>Myrica cerifera</i>	0.1								
<i>Celtis occidentalis</i>	0.1								
<i>Cyperus virens</i>	0.1								
<i>Hydrocotyle verticillata</i>	0.9								
<i>Juncus roemerianus</i>	0.7								
<i>Polygonum hydropiperoides</i>	19.4								
<i>Zizaniopsis miliacea</i>	28.1								
<i>Pontederia cordata</i>	14.9								
<i>Sagittaria falcata</i>	11.3								
<i>Alternanthera philoxeroides</i>	23.3								
<i>Justicia ovata</i>	0.2								
<i>Pluchea rosea</i>	0.1								
<i>Iris hexagona</i> var. <i>savannarum</i>	0.0								
<i>Uniola laxa</i>	7.0								
<i>Gramineae</i>	5.8								
<i>Callicarpa americana</i>	5.9								
<i>Panicum scoparium</i>	1.0								
<i>Carex</i> sp.	1.3								
<i>Oplismenus setarius</i>	3.3								
<i>Smilax bona-nox</i>	0.1								
<i>Pinus taeda</i>	0.1								
<i>Elephantopus carolinianus</i>	1.8								
<i>Sabal minor</i>	0.8								
<i>Anisostichus capreolata</i>	1.1								
<i>Vitis rotundifolia</i>	0.1								
	0.7								
	0.6								

Source: ESZ, 1981.

**Table C-2**  
**Species Composition by Zone at Site A2, Shown as Importance Value**

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Overstory Stratum</b>									
<i>Nyssa aquatica</i>	75.0	29.3	24.9						
<i>Salix nigra</i>	25.0	0.7							
<i>Cephalanthus occidentalis</i>		1.5							
<i>Acer rubrum</i>	55.6	25.1							
<i>Planera aquatica</i>	6.3	0.4							
<i>Liquidambar styraciflua</i>	3.7	23.8							
<i>Carpinus caroliniana</i>	3.0	10.9	26.9						
<i>Tilia americana</i>		6.3							
<i>Morus rubra</i>		0.8							
<i>Quercus michauxii</i>		2.7	1.4						
<i>Carya aquatica</i>		1.3	3.4						
<i>Ostrya virginiana</i>		1.9	6.1						
<i>Quercus nigra</i>		1.9							
<i>Diospyros virginiana</i>		2.0							
<i>Magnolia grandiflora</i>									
<i>Juniperus silicicola</i>									
<i>Nyssa sylvatica</i> var. <i>biflora</i>									
<i>Gleditsia triacanthos</i>									
<i>Ulmus alata</i>							1.8		
<b>Shrub Stratum</b>									
<i>Cephalanthus occidentalis</i>	100.0	100.0							
<i>Acer rubrum</i>							10.0		
<i>Fraxinus caroliniana</i>						2.5			
<i>Diospyros virginiana</i>					2.5		3.3		
<i>Vitis aestivalis</i>					15.0	13.4		31.0	
<i>Carpinus caroliniana</i>					41.0	69.5		35.4	
<i>Callicarpa americana</i>							8.1		

(Continued)

Table C-2 (Continued)

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Shrub Stratum (Continued)</b>									
<i>Liquidambar styraciflua</i>					2.4				
<i>Carya cordiformis</i>					3.3	4.5			
<i>Smilax</i> sp.						1.8			
<i>Ulmus alata</i>						27.3			
<b>Herbaceous Stratum</b>									
<i>Alternanthera philoxeroides</i>	45.6	47.3	0.3						
<i>Saururus cernuus</i>	23.6	8.3	1.2						
<i>Lemna minor</i>	8.1	29.5	2.7						
<i>Mikania scandens</i>	12.3	3.4	0.3						
<i>Boehmeria cylindrica</i>	0.2								
<i>Lycopus</i> sp.	0.3								
<i>Echinodorus cordifolius</i>	1.5	0.1							
<i>Lianobium spongia</i>	4.3	0.3							
<i>Ludwigia repens</i>	2.3		0.5						
<i>Eragrostis</i> sp.	0.1	0.1							
<i>Polygonum hydropiperoides</i>	0.3	4.2							
<i>Spirodella polyrhiza</i>	1.7	6.8							
<i>Fraxinus caroliniana</i>									
Unknown									
<i>Woodwardia areolata</i>									
<i>Perilla frutescens</i>									
<i>Ipomoea lacunosa</i>									
<i>Lobelia cardinalis</i>									
Unknown									
<i>Ampelopsis arborea</i>									
<i>Arundinaria gigantea</i>									
<i>Smilax</i> sp.									
<i>Anisostichus capreolata</i>									
<i>Hypoxis hirsuta</i>									
<i>Rhus radicans</i>									

(Continued)

Table C-2 (Concluded)

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Herbaceous Stratum (Continued)</b>									
<i>Carpinus caroliniana</i>				8.0	6.9	2.3			
<i>Botrychium biternatum</i>			0.2	0.8	0.8				
<i>Acer rubrum</i>			1.3	1.8	0.5				
<i>Juniperus laxa</i>			11.6	26.4	15.3				
<i>Quercus spp.</i>			0.3	1.5	0.6				
<i>Rubus trivialis</i>			0.8	1.6	0.1				
<i>Callicarpa americana</i>			1.0	2.4	3.8				
<i>Parthenocissus quinquefolia</i>				0.5	0.4				
<i>Verbesina virginica</i>				2.9	1.8				
<i>Acalypha gracilens</i>				1.3	2.3				
<i>Oplismenus setarius</i>				2.5	1.2				
<i>Panicum sp.</i>				0.3	0.1				
<i>Elephantopus tomentosus</i>				1.0	5.4				
<i>Elephantopus carolinianus</i>				1.8	5.8				
<i>Coronilla florida</i>				0.4					
<i>Asplenium platyneuron</i>				0.2					
<i>Carya aquatica</i>					0.1	0.5			
<i>Mitchella repens</i>					0.7	8.4			
<i>Gramineae</i>					0.3	2.6			
<i>Cercis canadensis</i>					0.5	0.1			
<i>Oxalis sp.</i>					0.6	1.7			
<i>Vitis rotundifolia</i>					0.9	5.5			
<i>Verbesina walteri</i>					0.3	0.5			
<i>Spilanthes americana</i>						0.1			
<i>Liquidambar styraciflua</i>						0.4			
<i>Ulmus alata</i>						0.8			
<i>Dicentra cucullaria</i>						0.8			
<i>Leersia virginica</i>						0.8			
<i>Symplocos tinctoria</i>						0.5			
<i>Agrimonia rostellata</i>						0.4			

Source: ESE, 1981.

(Sheet 3 of 3)

**Table C-3**  
**Species Composition by Zone at Site B1, Shown as Importance Value**

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-79m	Zone 8 70-79m	Zone 9 80-89m
<b>Overstory Stratum</b>									
<i>Pinus taeda</i>	36.1	34.5	28.0	21.8	22.3	17.8			
<i>Liquidambar styraciflua</i>	21.4	21.8	12.4	12.8	27.0	13.8			
<i>Carpinus caroliniana</i>	11.4	10.9	13.4	23.5	15.0	21.9			
<i>Nyssa sylvatica</i> var. <i>biflora</i>	10.8	1.0		3.3	2.0	1.0			
<i>Quercus falcata</i>	6.2	4.3	9.0	5.0	5.2	14.0			
<i>Ostrya virginiana</i>	4.6	5.6	3.7						
<i>Quercus nigra</i>	3.6	3.9	4.2	7.9	4.3	8.2			
<i>Diospyros virginiana</i>	1.6	0.6							
<i>Vitis rotundifolia</i>	1.3	1.8	4.1	2.1	3.8	7.7			
<i>Smilax bona-nox</i>	0.7	0.6							
<i>Magnolia virginiana</i>	0.7	2.8	3.6						
<i>Magnolia grandiflora</i>	0.7	8.3	2.6						
<i>Quercus michauxii</i>	0.7	2.2	7.9	2.3	4.5	2.9			
<i>Quercus nuttallii</i>	0.9		3.9	1.7					
<i>Carya glabra</i>	0.3		1.4	0.6	5.3	3.2			
<i>Sassafras albidum</i>			1.1	2.1					
<i>Fagus grandifolia</i>			2.8	11.5	3.1	2.7			
<i>Ulmus alata</i>			2.0	3.3	7.1	5.2			
<i>Ilex opaca</i>			2.1						
<i>Symplocos tinctoria</i>			0.6	0.5	1.8				
<b>Shrub Stratum</b>									
<i>Vitis rotundifolia</i>									
<i>Anisostichus capreolata</i>	58.3	74.7	32.1	24.5	29.2	26.1			
<i>Liquidambar styraciflua</i>	25.0		4.2	0.9	4.8	6.7			
<i>Callicarpa americana</i>	11.1								
<i>Nyssa sylvatica</i> var. <i>biflora</i>	5.6		14.3	27.8	61.9	53.6			
<i>Rhus radicans</i>		6.7	4.2	3.3	4.2				
	12.0								

(Continued)

Table C-3 (Continued)

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Shrub Stratum (Continued)</b>									
<i>Parthenocissus quinquefolia</i>	3.3	3.3	3.3						
<i>Carpinus caroliniana</i>	3.3								
<i>Stewartia malachodendron</i>				41.7	32.1				
<i>Phytolacca americana</i>				3.6					
<i>Brunnichia cirrhosa</i>					3.3				
<i>Sassafras albidum</i>					4.7				
<i>Carya glabra</i>						5.0			
<i>Symplocos tinctoria</i>							4.4		
								4.4	
<b>Herbaceous Stratum</b>									
<i>Nyssa sylvatica</i> var. <i>biflora</i>	0.1								
<i>Panicum scoparium</i>	1.6								
<i>Rubus betulifolius</i>	0.1								
<i>Woodwardia areolata</i>	1.6								
<i>Campsis radicans</i>	0.3								
<i>Vitis rotundifolia</i>	0.3								
<i>Ostrya virginiana</i>	0.1								
<i>Botrychium biternatum</i>	0.1								
<i>Quercus nigra</i>	0.1								
<i>Viola esculenta</i>	0.1								
<i>Uniola laea</i>	45.3	39.8	4.6						
<i>Anisostichus capreolata</i>	2.3	2.1	1.0						
<i>Panicum</i> sp.	1.8	3.0	0.6						
<i>Smilax</i> spp.	1.1	1.4	0.1						
<i>Arundinaria gigantea</i>	1.4	1.0	0.2						
<i>Calium pilosum</i>	0.5								
<i>Gramineae</i>	2.9	0.7	6.9						
<i>Carex</i> sp.	2.2	0.2	3.1	3.2	5.3				

(Continued)

Table C-3 (Concluded)

Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
	0-9m	10-19m	20-29m	30-39m	40-49m	50-59m	60-69m	70-79m	80-89m
<b>Herbaceous Stratum (Continued)</b>									
<i>Mitchella repens</i>	0.5	0.9	0.7		0.1		0.2		
<i>Callicarpa americana</i>	0.1		0.1	0.2	0.1	0.1	0.5		
<i>Rhus radicans</i>		0.3		0.1	0.1	0.1	0.1		
<i>Justicia ovata</i>		0.1	0.1	0.1	0.1	0.1	0.3		
<i>Oplismenus setarius</i>	38.1	50.2	81.6	86.6	88.8				
<i>Quercus falcata</i>		0.1							
<i>Ampelopsis arborea</i>		0.1							
<i>Saururus cernuus</i>		0.1							
<i>Arisaema triphyllum</i>		0.2	0.3						
<i>Passiflora lutea</i>		0.3	0.6						
<i>Selaginella ludoviciana</i>		0.1							
<i>Berchemia scandens</i>		0.1							
<i>Stewartia malachodendron</i>		0.1							
<i>Vaccinium ellottii</i>		0.1							
<i>Elephantopus carolinianus</i>	0.1			0.4	0.1				
<i>Hypoxis hirsuta</i>			0.5	0.4	2.9				
<i>Parthenocissus quinquefolia</i>			0.1		0.2				
<i>Lonicera japonica</i>				0.1	0.1				
<i>Cuphea carthagensis</i>					0.1				
<i>Sassafras albidum</i>					0.1	0.1			
<i>Ilex vomitoria</i>					0.1				
<i>Crataegus</i> sp.					0.1				

Table C-4  
Species Composition by Zone at Site B2, Shown as Importance Value

Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
	0-9m	10-19m	20-29m	30-39m	40-49m	50-59m	60-69m	70-79m	80-89m
<b>Overstory Stratum</b>									
<i>Taxodium distichum</i>	19.3								
<i>Ostrya virginiana</i>	2.0								
<i>Carya aquatica</i>	3.2								
<i>Cephalanthus occidentalis</i>	0.6								
<i>Nyssa aquatica</i>	30.7								
<i>Acer rubrum</i>	4.3								
<i>Ulmus americana</i>	3.3								
<i>Quercus nigra</i>	3.1								
<i>Liquidambar styraciflua</i>	6.2								
<i>Carpinus caroliniana</i>	21.6								
<i>Quercus michauxii</i>	2.4								
<i>Vitis rotundifolia</i>	1.0								
<i>Quercus falcata</i>	2.3								
<i>Fraxinus caroliniana</i>	4.5								
<i>Robinia pseudoacacia</i>	2.4								
<i>Rhus copallina</i>	1.3								
<i>Crataegus crus-galli</i>	1.3								
<i>Populus heterophylla</i>	1.1								
<i>Cornus florida</i>	0.9								
<i>Ulmus alata</i>	1.3								
<i>Juniperus silicicola</i>	0.4								
<i>Smilax sp.</i>	0.5								
<i>Ilex opaca</i>									
<i>Sapium sebiferum</i>									
<i>Ilex decidua</i>									
<i>Pinus glabra</i>									

(Continued)

(Sheet 1 of 5)

Table C-4 (Continued)

Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
	0-9m	10-19m	20-29m	30-39m	40-49m	50-59m	60-69m	70-79m	80-89m
<b>Shrub Stratum</b>									
<i>Taxodium distichum</i>	29.2								
<i>Carpinus caroliniana</i>	70.8	71.0	73.0	56.6	11.2	32.5	6.7		
<i>Cornus Florida</i>		26.3	10.7	7.0	3.4				
<i>Smilax bona-nox</i>		2.6	4.0	1.6	0.2				
<i>Celtis laevigata</i>			7.0						
<i>Vitis rotundifolia</i>			4.0						
<i>Rhus copallina</i>			4.5	14.6	6.1	0.5	0.4		
<i>Symplocos tinctoria</i>			6.7	0.5	6.6	0.9	0.2		
<i>Crataegus crus-galli</i>			0.7	0.2					
<i>Liquidambar styraciflua</i>				1.1					
<i>Gelsemium sempervirens</i>				0.3	3.4	0.4	2.4		
<i>Ostrya virginiana</i>				8.1	6.2	1.1	1.9		
<i>Pinus glabra</i>				4.2	27.5	10.4	19.9		
<i>Quercus nigra</i>				2.1	9.4	6.2	6.7		
<i>Callicarpa americana</i>					3.5	3.1	12.5		
<i>Vaccinium elliotti</i>					1.9		8.6		
<i>Morus rubra</i>					6.0				
<i>Rubus argutus</i>					1.9				
<i>Campsis radicans</i>					1.2		22.3		
<i>Quercus lyrata</i>					3.9	4.5	0.4		
<i>Quercus phellos</i>					4.0	4.8	5.9		
<i>Ulmus alata</i>						14.6	12.0		
<i>Smilax rotundifolia</i>						0.7	1.7		
<i>Ilex vomitoria</i>						2.6	0.2		
Unknown vine						2.6	2.5		
<i>Sapium sebiferum</i>						1.8	0.2		
<i>Carya glabra</i>						2.3			
<b>Herbaceous Stratum</b>									
<i>Vitis aestivalis</i>						0.8			
<i>Justicia ovata</i>						0.5			
<i>Alternanthera philoxeroides</i>						0.2			
<i>Hydrocotyle verticillata</i>						0.2			

(Continued)

(Sheet 2 of 5)

Table C-4 (Continued)

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Herbaceous Stratum (Continued)</b>									
<i>Panicum dictyonium</i>	0.3								
<i>Acalypha gracilens</i>	0.3								
<i>Arundinaria gigantea</i>	8.8	6.1							
<i>Brunnichia cirrhosa</i>	0.5								
<i>Carya aquatica</i>	1.4								
Unknown seedling	1.6	1.2							
<i>Berchemia scandens</i>	1.2								
<i>Fraxinus caroliniana</i>	1.4	1.4							
<i>Smilax sp.</i>	0.4	5.1							
<i>Ulmus americana</i>	2.1	10.2	2.4						
<i>Vaccinium</i> sp.	0.2								
Unknown seedling		0.7							
<i>Symplocos tinctoria</i>		2.2							
<i>Rhus radicans</i>			3.6						
<i>Ilex</i> sp.			1.3						
Unknown herb			0.4						
<i>Hypoxis hirsuta</i>	10.6	18.0	10.1						
<i>Rhus radicans</i>	1.1	0.6	6.8						
<i>Mitchella repens</i>	3.4	4.9	18.8						
<i>Carpinus caroliniana</i>	10.9	5.4	23.0						
<i>Borrichium binternatum</i>	0.2	2.5	2.6						
<i>Rueilia carolinensis</i>	0.2								
<i>Smilax pumila</i>	1.5	2.0	3.0						
<i>Uniola lata</i>	52.1	38.5	3.3						
<i>Viburnum obovatum</i>	0.6	1.9	3.8						
<i>Gramineae</i>	1.1	4.0							
<i>Quercus</i> seedling		0.2	2.1						
<i>Smilax bona-nox</i>	0.3								
<i>Acer rubrum</i>	0.3	0.4							

(Continued)

(Sheet 3 of 5)

Table C-4 (Continued)

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
	<b>Herbaceous Stratum (Continued)</b>								
<i>Perilla frutescens</i>	0.3	0.8	0.7	0.5	0.5	0.3	0.3	0.7	
<i>Eupatorium coelestisnum</i>	0.5	0.7	0.7	0.5	0.5	1.3	1.3	0.7	
<i>Rubus argutus</i>						3.9	3.9	4.6	
<i>Dicentra cucullaria</i>		0.5	0.7	0.4	0.4	8.7	8.7	3.1	
<i>Gramineae</i>		0.2		0.5	0.5	4.0	4.0	2.9	
<i>Elephantopus tomentosus</i>		2.9		1.3	1.3	2.1	2.1	6.5	
<i>Cornus florida</i>	4.6	2.5	3.1	10.1	10.1	3.3	3.3		
<i>Gelsemium sempervirens</i>			0.7	3.2	12.7	9.1			
<i>Campsis radicans</i>		1.3			0.9	0.1			
<i>Aristolochia serpentaria</i>				0.5	0.5	0.2	0.2		
<i>Ulmaceae seedling</i>				0.5	0.5	0.2	0.2	0.3	
<i>Callicarpa americana</i>				0.9	0.9	0.4	0.4	4.0	
<i>Axonopus affinis</i>				0.5	0.5	7.6	7.6	9.0	
<i>Lycopus rubellus</i>				1.8	1.8	1.6	1.6	2.3	
<i>Ostrya virginiana</i>		0.4		6.4	6.4	3.9	3.9		
<i>Sedge</i>						0.4	0.4		
<i>Panicum</i>						0.1	0.1		
<i>Sapium sebiferum</i>						0.3	0.3		
<i>Vaccinium stamineum</i>						0.3	0.3		
<i>Panicum aciculare</i>						0.7	0.7		
<i>Ilex opaca</i>						0.2	0.2		
<i>Viola esculenta</i>						0.8	0.8		
<i>Aristolochia serpentaria</i>						0.3	0.3		
<i>Unknown seedling</i>						0.1	0.1		
<i>Unknown herb</i>						0.1	0.1		
<i>Centella asiatica</i>						0.7	0.7		
<i>Vaccinium elliotii</i>						0.5	0.5		
<i>Paspalum notatum</i>						1.9	1.9	1.3	
<i>Ulmus alata</i>						0.4	0.4	3.8	

(Continued)

(Sheet 4 of 5)

Table C-4 (Concluded)

Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
	<u>0-9m</u>	<u>10-19m</u>	<u>20-29m</u>	<u>30-39m</u>	<u>40-49m</u>	<u>50-59m</u>	<u>60-69m</u>	<u>70-79m</u>	<u>80-89m</u>
<b>Herbaceous Stratum (Continued)</b>									
<b>Graminoid</b>									
<i>Rumex</i> (unknown rosette)									
<i>Quercus falcata</i>									
<i>Vaccinium arboreum</i>									
<i>Gnaphalium obtusifolium</i>									
<i>Vitis</i> sp.									
<i>Oxalis</i> sp.									
<i>Galactia volubilis</i>									
<i>Pinus glabra</i>									
<i>Lonicera japonica</i>									
<i>Solidago rugosa</i>									
Legume seedling									
<i>Quercus nigra</i>									
Vaccinium seedling	<b>0.9</b>								
<i>Acalypha gracilens</i>									
<i>Juniperus silicicola</i>									
Unknown herb									
<i>Hypericum hypericoides</i>									
<i>Fagus grandifolia</i>									
<i>Liquidambar styraciflua</i>									
<i>Celtis laevigata</i>									
<i>Quercus phellos</i>									
Unknown vine									
Unknown seedling									
<i>Vitis</i> seedling									
<i>Trichostema dichotomum</i>									

Source: ESE, 1981.

(Sheet 5 of 5)

**Table C-5**  
**Species Composition by Zone at Site C1, Shown as Importance Value**

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Overstory Stratum</b>									
<i>Myrica cerifera</i>	33.3		29.3		18.6		10.5		2.6
<i>Nyssa aquatica</i>	29.0								
<i>Pinus taeda</i>	28.7		50.4		47.2		47.9		66.4
<i>Salix nigra</i>	7.2		4.4		10.1		11.6		
<i>Liquidambar styraciflua</i>	1.7				4.6		12.0		13.1
<i>Nyssa sylvatica</i> var. <i>biflora</i>					18.3		12.0		
<i>Cephalanthus occidentalis</i>					1.2				
<i>Quercus nigra</i>							2.2		
<i>Sapium sebiferum</i>							3.8		
<i>Quercus virginiana</i>								12.7	
<i>Carya glabra</i>							5.2		5.2
<b>Shrub Stratum</b>									
<i>Myrica cerifera</i>	49.4	91.7	62.0	42.5	69.8	76.4	96.1	57.7	60.5
<i>Cephaelanthus occidentalis</i>	45.5			1.6	2.4				5.4
<i>Daubentonia texana</i>	2.6	4.2							
<i>Brunnichia cirrhosa</i>	2.5								
<i>Ampelopsis arborea</i>	4.2		3.9				3.0		2.0
<i>Baccharis halimifolia</i>			18.4	6.4	13.6				
<i>Sapium sebiferum</i>			9.1					3.1	
<i>Sabal minor</i>			6.1	38.5	14.2	23.6	0.6	13.9	10.9
<i>Gleditsea triacanthos</i>			0.5	11.0					
<i>Nyssa sylvatica</i> var. <i>biflora</i>							0.3		
<i>Campsis radicans</i>								10.4	
<i>Pinus taeda</i>								4.4	5.4
<i>Diospyros virginiana</i>								3.1	7.8
<i>Ilex vomitoria</i>									15.4

(Continued)

(Sheet 1 of 3)

AD-R138 643

WETLANDS RESEARCH PROGRAM EVALUATION OF METHODS FOR  
SAMPLING VEGETATION A. (U) ENVIRONMENTAL SCIENCE AND  
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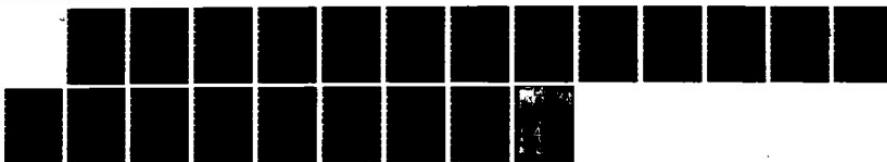
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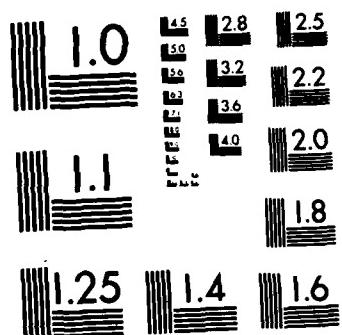
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MICROCOPY RESOLUTION TEST CHART  
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Table C-5 (Continued)

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Herbaceous Stratum</b>									
<i>Eichornia crassipes</i>	10.3								
Unknown grass		0.7							
<i>Clitoria mariana</i>		0.5							
<i>Spirodella polyrhiza</i>		0.4							
<i>Iris hexagona</i> var. <i>savannarum</i>		0.2							
<i>Cyperus</i>	0.6	0.4							
<i>Daubentonia texana</i>	0.1	0.3							
<i>Pluchea rosea</i>		0.5	0.1						
<i>Sagittaria falicata</i>	5.6	2.5	2.3						
<i>Sagittaria latifolia</i>	1.6	0.3	0.4						
<i>Peltandra virginica</i>	1.5	0.9	1.4						
Grass	1.3	1.6	0.5						
<i>Sporobolus</i> sp.	1.0	2.6	0.8						
<i>Baccharis halimifolia</i>		0.8							
<i>Pontederia cordata</i>	2.4			3.9					
<i>Hibiscus lasiocarpus</i>		0.3	0.7	0.1					
<i>Cephaelanthus occidentalis</i>	0.3				0.4				
<i>Lemna minor</i>	1.0				0.2				
<i>Saururus cernuus</i>	1.3	4.4	3.1	6.6	1.8				
<i>Myrica cerifera</i>		0.1	1.1	0.3		32.7	12.7		
<i>Ipomoea sagittata</i>						0.8	7.6		
<i>Brunnichia cirrhosa</i>		0.3		0.3			1.4		
<i>Mikania scandens</i>	0.4	1.2	0.1	1.5				7.2	
<i>Sabal minor</i>	1.0		1.8	0.4	10.8	1.9	0.4	1.0	
<i>Hydrocotyle verticillata</i>	0.4		0.6	1.1	3.4	1.7	29.9	2.7	
<i>Polygonum hydropiperoides</i>	51.4	59.4	74.3	62.8	70.9	40.1	20.4	30.2	38.6

(Continued)

(Sheet 2 of 3)

Table C-5 (Concluded)

Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
	<u>0-9m</u>	<u>10-19m</u>	<u>20-29m</u>	<u>30-39m</u>	<u>40-49m</u>	<u>50-59m</u>	<u>60-69m</u>	<u>70-79m</u>	<u>80-89m</u>
<b>Herbaceous Stratum (Continued)</b>									
<i>Alternanthera philoxeroides</i>	19.9	23.5	12.1	23.2	8.3	17.3	0.4	3.5	0.6
<i>Ampelopsis arborea</i>					0.3	3.3	4.6	10.9	10.9
<i>Campsis radicans</i>					2.9	0.4	4.1	4.5	27.7
<i>Commelinia virginica</i>					0.4	17.8	0.7	13.0	
<i>Rubus betulifolius</i>					0.7	34.8			
<i>Quercus virginiana</i>					0.6	0.6			
<i>Smilax bona-nox</i>						0.5	0.5	0.3	0.3
<i>Acer rubrum</i>							0.3	0.3	
<i>Quercus nigra</i>							0.3	0.3	
<i>Carya glabra</i>							1.6	1.6	
<i>Cyperaceae</i>					1.6				

Source: ESE, 1981.

(Sheet 3 of 3)

**Table C-6**  
**Species Composition by Zone at Site C2, Shown as Importance Value**

Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
	0-9m	10-19m	20-29m	30-39m	40-49m	50-59m	60-69m	70-79m	80-89m
<b>Overstory Stratum</b>									
<i>Cephalanthus occidentalis</i>	3.7	0.8							
<i>Acer rubrum</i>	27.2	33.7	32.6						
<i>Salix nigra</i>	10.2	10.3	1.9						
<i>Fraxinus caroliniana</i>	1.4	0.5	2.6						
<i>Nyssa aquatica</i>	57.5	51.2	62.9	99.3	67.2	46.9			
<i>Liquidambar styraciflua</i>		3.6		0.7	17.6				
<i>Carpinus caroliniana</i>					14.7	35.2			
<i>Quercus michauxii</i>					0.7	7.4			
<i>Vitis rotundifolia</i>						3.8			
<i>Celtis laevigata</i>						3.3			
<i>Ulmus alata</i>						3.3			
<b>Shrub Stratum</b>									
<i>Cephalanthus occidentalis</i>	87.2	66.9	22.5	69.9	3.8				
<i>Acer rubrum</i>	12.8	32.0	71.3	29.4					
<i>Nyssa aquatica</i>		0.8	6.2		53.8				
<i>Brunnichia cirrhosa</i>		0.4							
<i>Fraxinus caroliniana</i>				0.8					
<i>Vitis rotundifolia</i>						33.1	44.4		
<i>Carpinus caroliniana</i>						5.5	14.0		
<i>Smilax bona-nox</i>						3.8			
<i>Smilax laurifolia</i>						33.6			
<i>Ampelopsis arborea</i>						5.6			
<i>Callicarpa americana</i>						2.2			

(Continued)

(Sheet 1 of 3)

Table C-6 (continued)

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
<b>Herbaceous Stratum</b>									
<i>Cabomba caroliniana</i>	31.2								
<i>Ludwigia repens</i>	8.0								
<i>Limnobium spongia</i>	1.9								
<i>Spirodela polyrhiza</i>	3.1	1.1							
<i>Cephaelanthus occidentalis</i>	0.9	4.2							
<i>Lemma minor</i>	54.9	78.1	33.3	100.0		5.0			
<i>Hikania scandens</i>	12.5								
<i>Saururus cernuus</i>	4.2	41.7							
<i>Acer rubrum</i>		25.0							
<i>Smytaxis bona-nox</i>						5.0	0.3		
<i>Eupatorium coelestium</i>						13.0	1.8		
<i>Berchemia scandens</i>						30.6	4.5		
<i>Mitchella repens</i>						5.0	4.5		
<i>Justicia ovata</i>						13.6	23.0		
<i>Carpinus caroliniana</i>						5.0	0.3		
<i>Solidago rugosa</i>						10.0	1.5		
<i>Cornus florida</i>						5.0			
<i>Leersia virginica</i>						7.8			
<i>Perilla frutescens</i>							0.1		
<i>Verbesina virginica</i>							0.1		
<i>Woodwardia areolata</i>							0.1		
<i>Botrychium biternatum</i>							0.3		
<i>Campsis radicans</i>							0.3		
<i>Hydrophylla lacustris</i>							0.3		
<i>Oplismenus setarius</i>							0.4		
<i>Brunnichia cirrhosa</i>							0.6		
<i>Rubus argutus</i>							1.2		
<i>Elephantopus caroliniana</i>							1.2		

(Continued)

(Sheet 2 of 3)

Table C-6 (Concluded)

Species	Zone 1 0-9m	Zone 2 10-19m	Zone 3 20-29m	Zone 4 30-39m	Zone 5 40-49m	Zone 6 50-59m	Zone 7 60-69m	Zone 8 70-79m	Zone 9 80-89m
	<b>Herbaceous Stratum (Continued)</b>								
<i>Quercus nigra</i>									2.9
<i>Symplocos tinctoria</i>									3.1
<i>Vitis vulpina</i>									3.4
<i>Anisostichus capreolata</i>									3.7
<i>Rhus radicans</i>									7.4
<i>Smilax pumila</i>									8.9
<i>Cyperaceae</i>									29.4

Source: ESE, 1981.

(Sheet 3 of 3)

**Table C-7**  
**Calculated Species Adaptation Numbers**  
**for Overstory Species**

<u>Species</u>	<u>SAN<sub>w</sub>*</u>	<u>SAN<sub>u</sub>**</u>	<u>SAN<sub>c</sub>†</u>	<u>VIV††</u>
<u>Ulmus americana</u>	10.00	1.42	7.04	6.15
<u>Magnolia virginiana</u>	10.00	2.50	4.00	6.92
<u>Nyssa aquatica</u>	10.00	3.01	3.32	10.00
<u>Taxodium distichum</u>	10.00	3.31	3.02	7.69
<u>Salix nigra</u>	8.33	2.71	3.07	10.00
<u>Fraxinum caroliniana</u>	7.77	1.98	3.92	7.69
<u>Pinus taeda</u>	7.56	7.40	1.02	6.15
<u>Cephalanthus occidentalis</u>	7.40	1.86	3.98	9.23
<u>Nyssa sylvatica</u> var. <u>biflora</u>	7.06	5.56	1.27	6.92
<u>Liquidambar styraciflua</u>	6.84	8.51	0.80	1.54
<u>Acer rubrum</u>	6.71	3.15	2.13	7.69
<u>Carya aquatica</u>	6.70	3.05	2.20	5.38
<u>Ostrya virginiana</u>	6.48	4.99	1.30	6.15
<u>Magnolia grandiflora</u>	6.16	6.46	0.95	4.62
<u>Smilax</u> sp.	6.00	2.00	3.00	6.15
<u>Quercus michauxii</u>	5.90	6.58	0.90	3.08
<u>Carpinus caroliniana</u>	5.67	9.05	0.63	2.31
<u>Quercus falcata</u>	5.40	8.33	0.65	3.08
<u>Daubentonia texana</u>	5.00	1.67	2.99	5.38
<u>Cyrilla racemiflora</u>	5.00	2.00	2.50	6.15
<u>Populus heterophylla</u>	5.00	2.00	2.50	4.62
<u>Ilex verticillata</u>	5.00	2.50	2.00	6.15
<u>Planera aquatica</u>	5.00	3.33	1.50	6.15
<u>Quercus nuttallii</u>	5.00	3.33	1.50	6.15
<u>Quercus phellos</u>	5.00	5.00	1.00	5.38
<u>Myrica cerifera</u>	4.97	5.42	0.92	4.62
<u>Diospyros virginiana</u>	4.93	4.38	1.13	5.38
<u>Vitis rotundifolia</u>	4.82	7.67	0.63	3.08
<u>Quercus nigra</u>	4.75	6.04	0.79	3.08
<u>Rhus copallina</u>	4.20	2.38	1.76	5.38
<u>Fagus grandiflora</u>	3.89	7.78	0.50	3.08
<u>Pinus glabra</u>	3.50	6.67	0.52	3.08
<u>Tilia americana</u>	3.40	3.33	1.02	5.38
<u>Morus rubra</u>	3.40	3.33	1.02	5.38
<u>Baccharis halimifolia</u>	3.33	2.50	1.33	5.38
<u>Quercus alba</u>	3.33	2.50	1.33	5.38
<u>Sassafras albidum</u>	3.33	3.33	1.00	5.38
<u>Rhododendron viscosum</u>	3.33	6.25	0.53	5.38
<u>Carya glabra</u>	3.33	10.00	0.33	2.31
<u>Halesia diptera</u>	3.33	10.00	0.33	4.62
<u>Vaccinium arboreum</u>	3.33	10.00	0.33	4.62
<u>Robinia pseudoacacia</u>	3.29	1.43	2.30	5.38
<u>Crataegus crus-galli</u>	3.29	2.00	1.65	5.38

(Continued)

Table C-7 (Concluded)

Species	<u>SAN<sub>w</sub></u> *	<u>SAN<sub>u</sub></u> **	<u>SAN<sub>c</sub></u> †	<u>VIV</u> ††
<u>Cornus florida</u>	3.29	2.00	1.65	3.85
<u>Symplocos tinctoria</u>	2.90	10.00	0.29	3.85
<u>Ilex opaca</u>	2.60	3.44	0.76	3.85
<u>Ulmus alata</u>	2.55	8.33	0.31	0.77
<u>Quercus laurifolia</u>	2.50	5.00	0.25	4.62
<u>Aesculus pavia</u>	2.35	10.00	0.24	3.85
<u>Quercus virginiana</u>	2.35	8.33	0.28	3.08
<u>Sapium sebifera</u>	2.27	3.89	0.58	3.08
<u>Gleditsia triacanthos</u>	2.25	8.33	0.27	3.08
<u>Ilex vomitoria</u>	2.25	10.00	0.23	3.85
<u>Ilex decidua</u>	2.00	3.33	0.60	3.85
<u>Juniperus silicicola</u>	2.00	6.08	0.33	3.85
<u>Carya cordiformis</u>	2.00	8.33	0.24	3.85
<u>Celtis laevigata</u>	1.67	10.00	0.17	3.08
<u>Oxydendron arboreum</u>	1.67	10.00	0.17	4.62
<u>Hamamelis virginiana</u>	1.67	10.00	0.17	4.62
<u>Castanea dentata</u>	1.67	10.00	0.17	4.62

\* When using SAN<sub>w</sub> values, 15 species with SAN<sub>w</sub> over 5.99 constituted wetland group, 28 species with SAN<sub>w</sub> between 3.29 and 5.99 constituted transition group, and 17 species with SAN<sub>w</sub> of 3.29 and below constituted upland group.

\*\* When using SAN<sub>u</sub> values, 15 species with lowest SAN<sub>u</sub> values constituted wetland group, next 28 species constituted transition group, and 17 species with highest SAN<sub>u</sub> values constituted upland group.

† When using SAN<sub>c</sub> values, 15 species with SAN<sub>c</sub> values over 2.50 constituted the wetland group, 28 species between 2.50 and 0.50 constituted the transition group, and 17 species with SAN<sub>c</sub> values below 0.50 constituted the upland group.

†† When using VIV values, 15 species with highest VIV values constituted wetland group, next 28 species constituted transition group, and 17 species with lowest VIV values constituted upland group.

Source: ESE, 1981.

Table C-8  
Calculated Species Adaptation Numbers  
for Shrub Species

Species	SAN <sub>w</sub> *	SAN <sub>u</sub> **	SAN <sub>c</sub> †	VIV††
<u>Taxodium distichum</u>	10.00	1.71	5.85	8.10
<u>Cephalanthus occidentalis</u>	9.00	3.47	2.59	10.00
<u>Iva frutescens</u>	7.78	4.17	1.87	6.67
<u>Nyssa aquatica</u>	7.50	3.50	2.14	8.10
<u>Daubentonia texana</u>	6.67	1.46	4.57	8.10
<u>Myrica cerifera</u>	6.17	6.33	0.97	8.10
<u>Anisostichus capreolata</u>	6.00	10.00	0.60	6.67
<u>Acer rubrum</u>	5.83	3.73	1.56	7.62
<u>Baccharis halimifolia</u>	5.56	4.00	1.39	7.14
<u>Nyssa sylvatica</u> var. <u>biflora</u>	5.48	3.44	1.59	7.62
<u>Fraxinus caroliniana</u>	5.28	2.89	1.83	7.62
<u>Brunnichia cirrhosa</u>	5.17	5.29	0.98	7.14
<u>Carpinus caroliniana</u>	5.08	8.40	0.60	4.29
<u>Ilex verticillata</u>	5.00	2.50	2.00	7.62
<u>Clethra alnifolia</u>	5.00	2.50	2.00	7.62
<u>Leucothoe axillaris</u>	5.00	2.50	2.00	7.62
<u>Parthenocissus quinquefolia</u>	5.00	3.33	1.50	7.62
<u>Cyrilla racemiflora</u>	5.00	5.00	1.00	7.14
<u>Prunus serotina</u>	5.00	5.00	1.00	6.67
<u>Rhus radicans</u>	5.00	5.00	1.00	7.14
<u>Cornus florida</u>	5.00	5.10	0.98	6.19
<u>Styrax grandifolia</u>	5.00	10.00	0.50	6.67
<u>Itea virginica</u>	5.00	10.00	0.50	7.14
<u>Vitis rotundifolia</u>	4.23	10.00	0.42	4.76
<u>Smilax</u> sp.	4.14	6.67	0.62	5.24
<u>Callicarpa americana</u>	3.73	7.67	0.49	4.76
<u>Sabal minor</u>	3.61	10.00	0.36	6.67
<u>Sebastiana ligustrina</u>	3.50	5.00	0.70	6.67
<u>Liquidambar styraciflua</u>	3.44	6.94	0.50	4.76
<u>Crataegus crus-galli</u>	3.33	2.50	1.33	7.14
<u>Phytolacca americana</u>	3.33	2.50	1.33	7.14
<u>Stewartia malachodendron</u>	3.33	3.33	1.00	7.14
<u>Rhododendron viscosum</u>	3.33	5.00	0.67	6.67
<u>Viburnum dentatum</u>	3.33	5.00	0.67	6.67
<u>Vitis aestivalis</u>	3.33	10.00	0.33	7.62
<u>Rhus copallina</u>	3.33	10.00	0.33	5.24
<u>Hibiscus casiocarpus</u>	3.33	5.00	0.67	6.67
<u>Pinus taeda</u>	2.92	6.11	0.48	6.67
<u>Ampelopsis arborea</u>	2.92	8.75	0.33	6.67
<u>Sapium sebifera</u>	2.78	8.33	0.33	6.19
<u>Ilex vomitoria</u>	2.56	10.00	0.26	5.24

(Continued)

(Sheet 1 of 3)

Table C-8 (Continued)

Species	<u>SAN<sub>w</sub></u> *	<u>SAN<sub>u</sub></u> **	<u>SAN<sub>c</sub></u> †	<u>VIV</u> ††
<u>Bumelia lycioides</u>	2.50	2.50	1.00	7.14
<u>Lyonia lucida</u>	2.50	3.33	0.75	7.14
<u>Magnolia grandiflora</u>	2.50	3.33	0.75	7.14
<u>Quercus michauxii</u>	2.50	3.33	0.75	7.14
<u>Juglans nigra</u>	2.50	3.33	0.75	7.14
<u>Forestiera acuminata</u>	2.50	5.00	0.50	6.67
<u>Ostrya virginiana</u>	2.50	5.00	0.50	5.24
<u>Symplocos tinctoria</u>	2.50	7.50	0.33	5.24
<u>Celtis laevigata</u>	2.50	8.33	0.30	5.71
<u>Vaccinium arboreum</u>	2.50	10.00	0.25	6.67
<u>Sassafras albidum</u>	2.50	10.00	0.25	7.14
<u>Carya cordiformis</u>	2.50	10.00	0.25	6.19
<u>Gelsemium sempervirens</u>	2.50	10.00	0.25	4.76
<u>Ilex opaca</u>	2.50	10.00	0.25	6.67
<u>Vaccinium stamineum</u>	2.50	10.00	0.25	6.67
<u>Oxydendron arboreum</u>	2.50	10.00	0.25	6.67
<u>Pinus glabra</u>	2.50	10.00	0.25	4.76
<u>Hamamelis virginiana</u>	2.50	10.00	0.25	7.14
<u>Castanea dentata</u>	2.50	10.00	0.25	6.67
<u>Rubus</u> spp.	2.44	6.67	0.37	5.24
<u>Gleditsea triacanthos</u>	2.33	3.33	0.70	6.67
<u>Diospyros virginiana</u>	2.27	7.50	0.30	0.48
<u>Rosa bracteata</u>	2.25	5.00	0.45	7.14
<u>Quercus nigra</u>	2.22	7.50	0.30	3.33
<u>Campsis radicans</u>	2.19	7.08	0.31	5.71
<u>Quercus virginiana</u>	2.14	10.00	0.21	6.67
<u>Sambucus canadensis</u>	2.00	2.00	1.00	7.14
<u>Morus rubra</u>	2.00	3.33	0.60	6.67
<u>Quercus alba</u>	2.00	5.00	0.40	7.14
<u>Quercus stellata</u>	2.00	5.00	0.40	6.67
<u>Vaccinium elliotii</u>	2.00	7.50	0.27	5.71
<u>Quercus lyrata</u>	2.00	10.00	0.20	5.71
<u>Carya glabra</u>	1.94	10.00	0.19	6.19
<u>Quercus phellos</u>	1.84	10.00	0.18	5.71
<u>Ulmus alata</u>	1.78	10.00	0.18	5.24
<u>Aralia spinosa</u>	1.67	10.00	0.17	6.67
<u>Cercis canadensis</u>	1.67	10.00	0.17	7.14
<u>Aesculus pavia</u>	1.67	10.00	0.17	6.19
Unknown vine	1.67	10.00	0.17	6.19

(Continued)

\* When using SAN<sub>w</sub> values, 7 species with SAN<sub>w</sub> over 6.00 constituted wetland group, 30 species with SAN<sub>w</sub> between 3.33 and 6.00 constituted transitional group, and 43 species with SAN<sub>w</sub> values below 3.33 constituted upland group.

(Sheet 2 of 3)

Table C-8 (Concluded)

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\*\* When using SAN<sub>u</sub> values, 7 species with lowest SAN<sub>u</sub> values constituted wetland group, next 30 species constituted transitional group, and 43 species with highest SAN<sub>u</sub> values constituted upland group.

† When using SAN<sub>c</sub> values, 7 species with SAN<sub>c</sub> values over 2.50 constituted the wetland group, 30 species between 2.50 and 0.50 constituted the transition group, and 43 species with SAN<sub>c</sub> values below 0.50 constituted the upland group.

†† When using VIV values, 7 species with highest VIV values constituted wetland group, next 30 species constituted transitional group, and 43 species with lowest VIV values constituted upland group.

Source: ESE, 1981.

(Sheet 3 of 3)

Table C-9  
Calculated Species Adaptation Numbers  
for Herbaceous Species

Species	SAN <sub>w</sub> *	SAN <sub>u</sub> **	SAN <sub>c</sub> †
<u>Eichornia crassipes</u>	10.00	1.11	9.00
<u>Daubentonia texana</u>	10.00	1.25	8.00
<u>Sagittaria latifolia</u>	10.00	1.43	6.99
<u>Peltandra virginica</u>	10.00	1.43	6.99
<u>Sporobolus</u> sp.	10.00	1.43	6.99
<u>Grass</u>	10.00	1.43	6.99
<u>Cabomba caroliniana</u>	10.00	1.67	5.99
<u>Nyssa sylvatica</u> var. <u>biflora</u>	10.00	1.67	5.99
<u>Vitis aestivalis</u>	10.00	1.67	5.99
<u>Panicum dichotomum</u>	10.00	1.67	5.99
<u>Ceratophyllum demersum</u>	10.00	2.00	5.00
<u>Lycopus rubellus</u>	10.00	2.00	5.00
<u>Boehmeria cylindrica</u>	10.00	2.00	5.00
Unknown seedling	10.00	2.00	5.00
<u>Limnobium spongia</u>	10.00	2.08	4.79
<u>Spirodella polyrhiza</u>	10.00	2.15	4.65
<u>Cephalanthus occidentalis</u>	10.00	2.33	4.28
<u>Echinodorus cordifolius</u>	10.00	2.50	4.00
<u>Eragrostis</u> sp.	10.00	2.50	4.00
<u>Sagittaria falcata</u>	10.00	2.98	3.36
<u>Scirpus</u> sp.	10.00	3.33	3.50
<u>Pontederia cordata</u>	10.00	3.38	2.95
<u>Spartina patens</u>	10.00	3.38	2.95
<u>Lemna minor</u>	10.00	4.58	2.18
<u>Ruellia caroliniensis</u>	10.00	5.00	2.00
<u>Cyperus virens</u>	10.00	3.33	3.00
<u>Alternanthera philoxeroides</u>	8.89	4.86	1.83
<u>Hydrocotyle verticillata</u>	8.33	4.58	1.82
<u>Mikania scandens</u>	8.33	7.78	1.07
<u>Ludwigia repens</u>	7.78	2.78	2.80
<u>Saururus cernuus</u>	7.67	3.00	2.56
<u>Carex</u> sp.	7.50	10.00	0.75
<u>Polygonum hydropiperoides</u>	7.33	5.67	1.29
<u>Smilax</u> sp.	7.08	7.50	0.94
<u>Eleocharis tuberculosa</u>	6.67	1.87	3.57
<u>Cyperus iria</u>	6.67	1.88	3.56
<u>Iva frutescens</u>	6.67	2.50	2.67
<u>Juncus roemerianus</u>	6.67	3.38	1.97
<u>Zizaneopsis miliacea</u>	6.67	3.38	1.97
<u>Iris hexagona</u>	6.67	5.72	1.17

(Continued)

(Sheet 1 of 5)

Table C-9 (Continued)

Species	SAN <sub>w</sub> *	SAN <sub>u</sub> **	SAN <sub>c</sub> †
<u>Arundinaria gigantea</u>	6.67	6.13	1.09
<u>Viburnum dentatum</u>	6.67	7.50	0.89
<u>Panicum</u> sp.	6.25	10.00	0.63
<u>Galium pilosum</u>	6.25	10.00	0.63
<u>Acalypha gracilens</u>	6.25	10.00	0.63
<u>Panicum scoparium</u>	6.11	5.00	1.22
<u>Sabal minor</u>	6.11	10.00	0.61
<u>Uniola laxa</u>	6.00	8.00	0.75
<u>Eupatorium coelestinum</u>	6.00	10.00	0.60
<u>Gramineae</u>	5.90	10.00	0.59
<u>Celtis laevigata</u>	5.83	10.00	0.58
<u>Ipomoea sagittata</u>	5.63	3.38	1.66
<u>Justicia ovata</u>	5.50	7.92	0.69
<u>Mitchella repens</u>	5.40	10.00	0.54
<u>Myrica cerifera</u>	5.33	3.75	0.53
<u>Hypoxis hirsuta</u>	5.28	10.00	0.52
<u>Callicarpa americana</u>	5.21	10.00	0.52
<u>Smilax bona-nox</u>	5.13	10.00	0.51
<u>Carpinus caroliniana</u>	5.11	10.00	0.51
<u>Clitoria mariana</u>	5.00	1.25	4.00
Unknown grass	5.00	1.25	4.00
<u>Caryophyllaceae</u>	5.00	1.72	2.92
<u>Leucothoe axillaris</u>	5.00	2.00	2.50
<u>Mollugo verticillata</u>	5.00	2.00	2.50
<u>Vaccinium</u> sp.	5.00	2.00	2.50
<u>Taxodium distichum</u>	5.00	2.50	2.00
<u>Ulmus americana</u>	5.00	5.00	1.00
<u>Ostrya virginiana</u>	5.00	3.50	1.43
<u>Botrychium biternatum</u>	5.00	8.00	0.62
<u>Pluchea rosea</u>	5.00	10.00	0.50
<u>Eryngium yuccifolia</u>	5.00	10.00	0.50
<u>Smilax pumila</u>	5.00	10.00	0.50
<u>Quercus</u> sp.	5.00	10.00	0.50
<u>Rubus betulifolius</u>	4.92	3.33	1.48
<u>Cornus florida</u>	4.83	5.00	0.97
<u>Acer rubrum</u>	4.44	10.00	0.44
<u>Woodwardia aerolata</u>	4.38	4.58	0.95
<u>Fraxinus caroliniana</u>	4.27	2.92	1.46
<u>Oplismenus setarius</u>	4.12	10.00	0.41
<u>Anisostichus capreolata</u>	4.07	8.67	0.47
<u>Vitis rotundifolia</u>	3.90	7.07	0.55

(Continued)

(Sheet 2 of 5)

Table C-9 (Continued)

Species	SAN <sub>w</sub> *	SAN <sub>u</sub> **	SAN <sub>c</sub> †
<u>Carya aquatica</u>	3.75	6.00	0.62
<u>Rhus radicans</u>	3.62	10.00	0.32
<u>Campsis radicans</u>	3.58	7.92	0.45
<u>Brunnichia cirrhosa</u>	3.55	7.40	0.48
<u>Viola esculenta</u>	3.50	3.75	0.93
<u>Dicentra cucullaria</u>	3.50	10.00	0.35
<u>Berchemia scandens</u>	3.44	5.56	0.62
<u>Rubus argutus</u>	3.33	10.00	0.33
<u>Panicum virgatum</u>	3.33	1.67	1.99
<u>Sacciolepsis striata</u>	3.33	1.67	1.99
<u>Baccharis halimifolia</u>	3.33	1.72	1.94
<u>Panicum hemitomon</u>	3.33	2.00	1.66
<u>Clethra alnifolia</u>	3.33	2.50	1.33
<u>Lilium sp.</u>	3.33	2.50	1.33
<u>Rhododendron viscosum</u>	3.33	2.50	1.33
<u>Ipomoea lacunosa</u>	3.33	2.50	1.33
<u>Lobelia cardinalis</u>	3.33	2.50	1.33
<u>Selaginella ludoviciana</u>	3.33	2.50	1.33
<u>Unknown seedling</u>	3.33	2.50	1.33
<u>Gramineae sp.</u>	3.33	3.33	1.00
<u>Unknown herb</u>	3.33	3.33	1.00
<u>Arisaema triphyllum</u>	3.33	3.33	1.00
<u>Passiflora lutea</u>	3.33	3.33	1.00
<u>Sebastiania exaltata</u>	3.33	5.00	0.67
<u>Unknown herb</u>	3.33	5.00	0.67
<u>Pinus taeda</u>	3.33	10.00	0.33
<u>Quercus sp.</u>	3.33	10.00	0.33
<u>Rubus trivialis</u>	3.33	10.00	0.33
<u>Elephantopus tomentosa</u>	3.33	10.00	0.33
<u>Gelsemium sempervirens</u>	2.92	10.00	0.29
<u>Hypericum hypericoides</u>	2.89	7.50	0.38
<u>Quercus falcata</u>	2.67	6.25	0.43
<u>Ampelopsis arborea</u>	2.67	7.50	0.35
<u>Vaccinium elliottii</u>	2.61	7.78	0.33
<u>Ilex sp.</u>	2.50	3.33	0.75
<u>Unknown herb</u>	2.50	3.33	0.75
<u>Stewartia malachodendron</u>	2.50	3.33	0.75
<u>Unknown shrub</u>	2.50	3.33	0.75
<u>Aristolochia serpentaria</u>	2.50	5.00	0.50
<u>Asplenium platyneuron</u>	2.50	5.00	0.50
<u>Rumex sp.</u>	2.50	5.00	0.50

(Continued)

(Sheet 3 of 5)

Table C-9 (Continued)

Species	SAN <sub>w</sub> *	SAN <sub>u</sub> **	SAN <sub>c</sub> †
<u>Geum</u> sp.	2.50	5.00	0.50
<u>Oxalis</u> sp.	2.50	10.00	0.25
<u>Cercis canadensis</u>	2.50	10.00	0.25
<u>Ulmaceae</u> seedling	2.50	10.00	0.25
<u>Lycopus rubellus</u>	2.50	10.00	0.25
<u>Vaccinium</u> seedling	2.50	10.00	0.25
<u>Axonopus affinus</u>	2.50	10.00	0.25
<u>Parthenocissus quinquefolia</u>	2.50	10.00	0.25
<u>Quercus nigra</u>	2.46	7.50	0.33
<u>Symplocas tinctoria</u>	2.38	8.33	0.28
<u>Ilex vomitoria</u>	2.33	8.33	0.28
<u>Stenotaphrum secundatum</u>	2.25	6.67	0.34
<u>Ilex opaca</u>	2.25	7.50	0.30
<u>Vaccinium stamineum</u>	2.25	7.50	0.30
<u>Vaccinium arboreum</u>	2.25	10.00	0.22
<u>Pinus glabra</u>	2.25	10.00	0.22
<u>Verbesina virginica</u>	2.08	10.00	0.21
<u>Diospyros virginiana</u>	2.00	3.33	0.60
<u>Sedge</u>	2.00	5.00	0.40
<u>Panicum</u>	2.00	5.00	0.40
<u>Panicum aciculare</u>	2.00	5.00	0.40
<u>Sapium sebiferum</u>	2.00	5.00	0.40
<u>Sassafras albidum</u>	2.00	5.00	0.40
<u>Quercus michauxii</u>	2.00	5.00	0.40
Unknown seedling	2.00	5.00	0.40
Unknown herb	2.00	5.00	0.40
<u>Solidago rugosa</u>	2.00	7.50	0.27
<u>Verbesina walteri</u>	2.00	10.00	0.20
<u>Spilanthes americana</u>	2.00	10.00	0.20
<u>Ulmus alata</u>	2.00	10.00	0.20
<u>Agrimony rostellata</u>	2.00	10.00	0.20
<u>Cuphea carthagensis</u>	2.00	10.00	0.20
<u>Centella asiatica</u>	2.00	10.00	0.20
<u>Paspalum notatum</u>	2.00	10.00	0.20
<u>Gnaphalium obtusifolium</u>	2.00	10.00	0.20
<u>Vitis</u> sp.	2.00	10.00	0.20
<u>Galactia volubilis</u>	2.00	10.00	0.20
Legume seedling	2.00	10.00	0.20
<u>Liquidambar styraciflua</u>	1.89	7.79	0.24
<u>Cyperaceae</u>	1.83	6.00	0.30
<u>Quercus virginiana</u>	1.83	6.11	0.30

(Continued)

(Sheet 4 of 5)

Table C-9 (Concluded)

Species	<u>SAN<sub>w</sub></u> *	<u>SAN<sub>u</sub></u> **	<u>SAN<sub>c</sub></u> †
<u>Leersia virginica</u>	1.83	10.00	0.18
<u>Lonicera japonica</u>	1.83	10.00	0.18
<u>Hibiscus lasiocarpus</u>	1.67	2.50	0.67
<u>Aesculus pavia</u>	1.67	5.00	0.33
<u>Hygrophila lacustris</u>	1.67	10.00	0.17
<u>Commelina virginica</u>	1.67	10.00	0.17
<u>Crataegus crus-galli</u>	1.67	10.00	0.17
<u>Trichostema dichotomum</u>	1.67	10.00	0.17
<u>Acanthos</u>	1.67	10.00	0.17
<u>Vitis vulpina</u>	1.67	10.00	0.17
Unknown herb	1.67	10.00	0.17
<u>Quercus phellos</u>	1.67	10.00	0.17
Unknown vine	1.67	10.00	0.17
Unknown seedling	1.67	10.00	0.17
<u>Vitis</u> seedling	1.67	10.00	0.17
<u>Fagus grandifolia</u>	1.67	10.00	0.17
<u>Juniperus silicicola</u>	1.67	10.00	0.17
<u>Polypodium polypodioides</u>	1.67	10.00	0.17
<u>Carya glabra</u>	1.67	10.00	0.17

\* When using SAN<sub>w</sub> values, 37 species with SAN<sub>w</sub> of 6.67 and over constituted the wetland group, 71 species with SAN<sub>w</sub> values between 6.67 and 2.00 constituted the transitional group, and 74 species with SAN<sub>w</sub> values of 2.00 and below constituted the upland group.

\*\* When using SAN<sub>u</sub> values, 37 species with lowest SAN<sub>u</sub> values constituted the wetland group, next 71 species constituted transitional group, and 74 species with highest SAN<sub>u</sub> values constituted the upland group.

† When using SAN<sub>c</sub> values, 37 species with SAN<sub>c</sub> values over 2.00 constituted the wetland group, 71 species with SAN<sub>c</sub> values between 2.0 and 0.50 constituted the transitional group, and 74 species with SAN<sub>c</sub> values under 0.50 constituted the upland group.

Source: ESE, 1981.

(Sheet 5 of 5)

**Table C-10**  
**Calculated Continuum Index Values for Phase II Sites**  
Based on Overstory Distribution

<u>Site</u>	<u>Zone</u>	<u>CI<sub>w-q1</sub></u>	<u>CI<sub>w-qn</sub></u>	<u>CI<sub>c-q1</sub></u>	<u>CI<sub>c-qn</sub></u>	<u>CI<sub>v-q1</sub></u>	<u>CI<sub>v-qn</sub></u>
A1	1	7.87	890.9	1.53	253.6	5.58	726.60
	2	6.20	773.2	1.05	110.7	4.27	452.71
	3	4.76	509.2	0.59	67.5	2.66	313.01
A2	1	9.17	958.3	3.20	325.8	10.00	1000.00
	2	7.14	756.8	2.20	238.2	6.70	792.78
	3	5.36	714.0	1.42	179.2	5.10	583.21
	4	5.85	650.5	1.40	100.2	4.81	322.85
	5	4.22	474.4	0.83	68.3	3.76	360.14
B1	1	6.27	674.3	1.31	89.2	4.50	444.66
	2	5.99	669.7	1.26	93.3	4.46	489.24
	3	5.45	632.5	1.02	88.6	3.84	402.85
	4	4.44	574.9	0.76	62.3	3.18	355.68
	5	2.53	595.2	0.68	65.6	2.69	311.22
	6	2.53	568.8	0.68	74.7	2.69	460.53
B2	1	6.97	928.2	2.13	230.0	5.27	632.92
	2	--	--	--	--	--	--
	3	5.57	724.8	2.03	142.9	4.67	332.22
	4	--	--	--	--	--	--
	5	4.11	531.8	1.04	80.5	3.42	239.83
	6	--	--	--	--	--	--
	7	4.10	451.4	0.75	60.1	2.77	243.71
	8	--	--	--	--	--	--
	9	--	--	--	--	--	--
C1	1	7.54	744.0	1.83	179.7	6.46	694.97 2
	--	--	--	--	--	--	--
	3	6.98	675.6	1.57	112.1	6.92	599.35
	4	--	--	--	--	--	--
	5	7.03	702.9	1.84	127.9	6.41	622.01
	6	--	--	--	--	--	--
	7	6.75	692.7	1.21	122.9	5.06	641.74
	8	--	--	--	--	--	--
	9	5.08	651.6	0.67	85.9	3.54	491.67

(Continued)

Table C-10 (Concluded)

<u>Site</u>	<u>Zone</u>	<u>CI<sub>w-ql</sub></u>	<u>CI<sub>w-qn</sub></u>	<u>CI<sub>c-ql</sub></u>	<u>CI<sub>c-qn</sub></u>	<u>CI<sub>v-ql</sub></u>	<u>CI<sub>v-qn</sub></u>
C2	1	8.04	815.2	3.28	300.3	8.92	931.09
	2	7.84	792.1	2.87	281.5	7.69	890.93
	3	8.20	883.7	3.11	294.2	8.84	918.69
	4	8.42	997.8	2.06	330.3	5.77	994.08
	5	7.10	879.8	1.41	274.1	4.23	735.21
	6	4.58	596.3	0.57	70.4	2.31	201.20

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Source: ESE, 1981.

Table C-11  
Calculated Continuum Index Values for Phase II Sites  
Based on Shrub Distributions

<u>Site</u>	<u>Zone</u>	<u>CI<sub>w-q1</sub></u>	<u>CI<sub>w-qn</sub></u>	<u>CI<sub>c-q1</sub></u>	<u>CI<sub>c-qn</sub></u>	<u>CI<sub>v-q1</sub></u>	<u>CI<sub>v-qn</sub></u>
A1	1	7.78	778.0	1.87	187.0	6.67	667.0
	2	5.62	503.9	1.11	88.2	7.15	733.5
	3	3.58	366.8	0.45	44.6	5.72	557.9
A2	1	9.00	900.0	2.59	259.0	10.00	1000.0
	2	9.00	900.0	2.59	259.0	10.00	1000.0
	3	5.13	595.5	1.20	125.3	6.27	675.6
	4	4.12	451.9	0.41	53.2	4.68	472.3
	5	3.37	350.4	0.40	38.6	5.72	568.4
B1	1	4.35	455.7	0.50	47.8	5.24	523.8
	2	4.96	446.0	1.02	61.0	6.29	531.6
	3	4.27	386.2	0.86	87.4	6.27	602.3
	4	4.37	381.4	0.78	79.8	6.55	590.0
	5	4.47	404.2	0.63	49.7	5.83	495.6
	6	3.48	436.2	0.41	44.8	5.79	510.1
B2	1	7.54	651.7	3.23	213.3	6.20	540.25
	2	4.74	502.9	0.73	70.0	5.24	481.0
	3	3.59	455.9	0.56	54.7	5.37	456.8
	4	3.32	438.1	0.59	57.6	5.11	474.1
	5	2.98	305.4	0.45	40.5	5.21	496.4
	6	2.85	326.2	0.40	39.7	5.24	489.7
	7	2.87	277.6	0.37	33.9	5.13	519.4
	8	--	--	--	--	--	--
	9	--	--	--	--	--	--
C1	1	6.75	769.3	2.28	180.1	8.34	683.2
	2	5.25	651.9	1.96	109.5	7.62	804.8
	3	3.90	575.7	0.68	92.6	6.91	759.9
	4	5.43	498.1	1.20	71.5	7.72	736.1
	5	6.21	614.0	1.33	97.9	7.98	681.4
	6	5.14	594.8	0.67	82.6	7.39	776.3
	7	4.67	653.6	0.81	94.8	7.27	804.7
	8	4.05	540.8	0.71	82.8	6.31	736.8
	9	4.04	515.8	0.48	71.5	5.43	679.9

(Continued)

Table C-11 (Concluded)

<u>Site</u>	<u>Zone</u>	<u>CI<sub>w-ql</sub></u>	<u>CI<sub>w-qn</sub></u>	<u>CI<sub>c-ql</sub></u>	<u>CI<sub>c-qn</sub></u>	<u>CI<sub>v-ql</sub></u>	<u>CI<sub>v-qn</sub></u>
C2	1	7.42	859.4	2.08	245.8	8.81	969.5
	2	6.88	792.4	1.82	225.3	8.22	922.2
	3	7.44	631.4	2.10	182.8	8.57	818.5
	4	6.70	804.7	2.00	228.4	8.27	929.1
	5	3.63	621.4	1.27	144.5	6.48	674.8
	6	0.49	422.6	0.49	50.8	5.14	495.3

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Source: ESE, 1981.

Table C-12  
Calculated Continuum Index Value for Phase II Sites  
Based on Herb SAN<sub>w</sub> Distributions

<u>Site</u>	<u>Zone</u>	<u>CI<sub>w-qn</sub></u>
A1	1	822.1
	2	773.6
	3	557.6
A2	1	870.9
	2	911.3
	3	610.3
	4	542.4
	5	490.8
B1	1	526.1
	2	503.6
	3	446.5
	4	437.6
	5	428.6
	6	434.3
B2	1	579.8
	2	553.4
	3	505.7
	4	474.9
	5	358.4
	6	369.6
C1	1	821.8
	2	781.3
	3	757.3
	4	784.8
	5	720.8
	6	747.2
	8	469.7
	9	495.7
C2	1	982.2
	2	970.3
	3	764.1
	4	1000.0
	5	531.1
	6	194.1

Source: ESE, 1981.

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